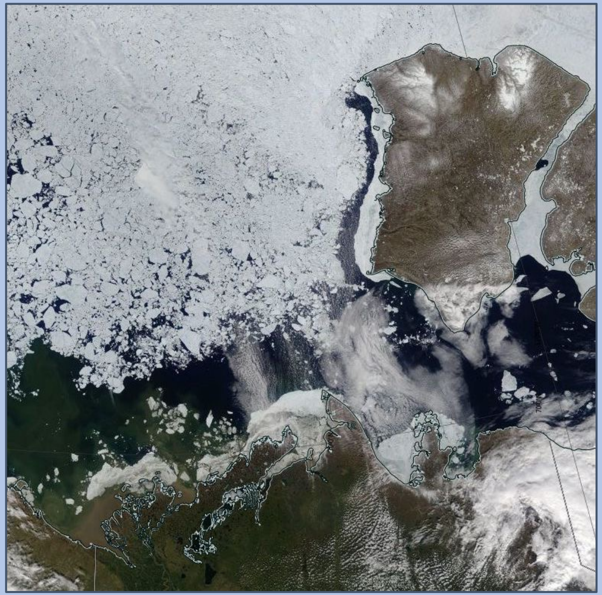


Passive microwave products at NSIDC

Summary of methods and usage

Walt Meier, NSIDC DAAC Scientist

National Snow and Ice Data Center
Advancing knowledge of Earth's frozen regions

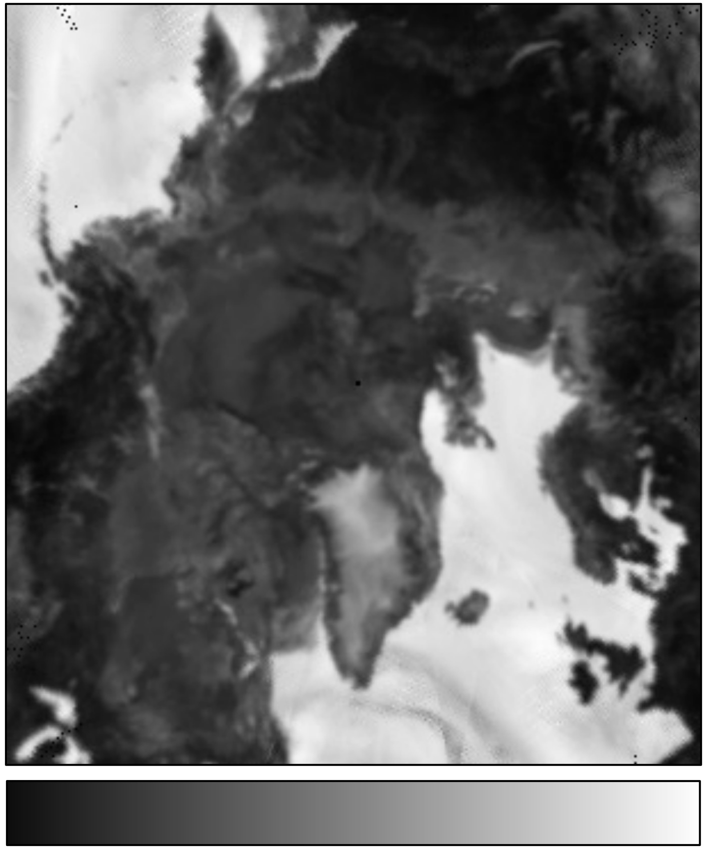
NASA Snow and Ice DAAC at NSIDC

- NSIDC established in 1978 as World Data Center for Glaciology
  - Work on NASA passive microwave data during 1980s led to DAAC
- DAAC established in 1993
- One of 12 current DAACs
- NSIDC includes DAAC, NOAA@NSIDC, science team, and others
- NASA archive includes AMSR-E/2, SMAP, ICESat, ICESat-2, MODIS and VIIRS snow and sea ice, polar passive microwave products from ESMR/SMMR/SSMI/SSMIS

Passive microwave RS for snow and ice

- Good contrast in sea ice and snow in the 19 GHz and 37 GHz channels
- Frequency and polarization differences accentuate contrast and filter some atmosphere

19V – 19H, 19 March 2018



F18 SSMIS gridded brightness temperatures

Water more polarized than ice
- 19V >> 19H for water
- 19V ≈ 19H for ice

Passive microwave RS for snow and ice

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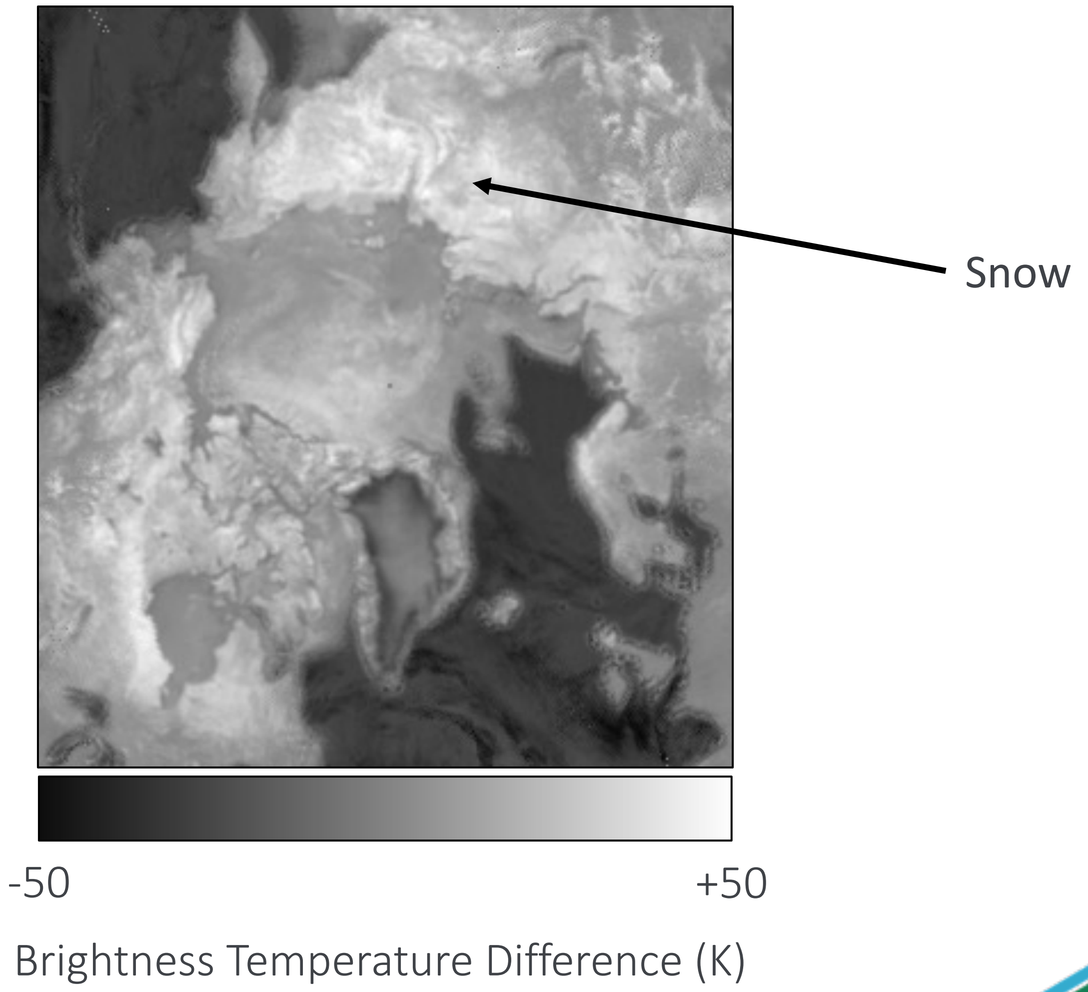
19H – 37H, 19 March 2018



F18 SSMIS gridded brightness temperatures

Sea ice PR and GR

Polarization Ratio:

$$PR_{[18V/H]} = \frac{T_B[18V] - T_B[18H]}{T_B[18V] + T_B[18H]}$$

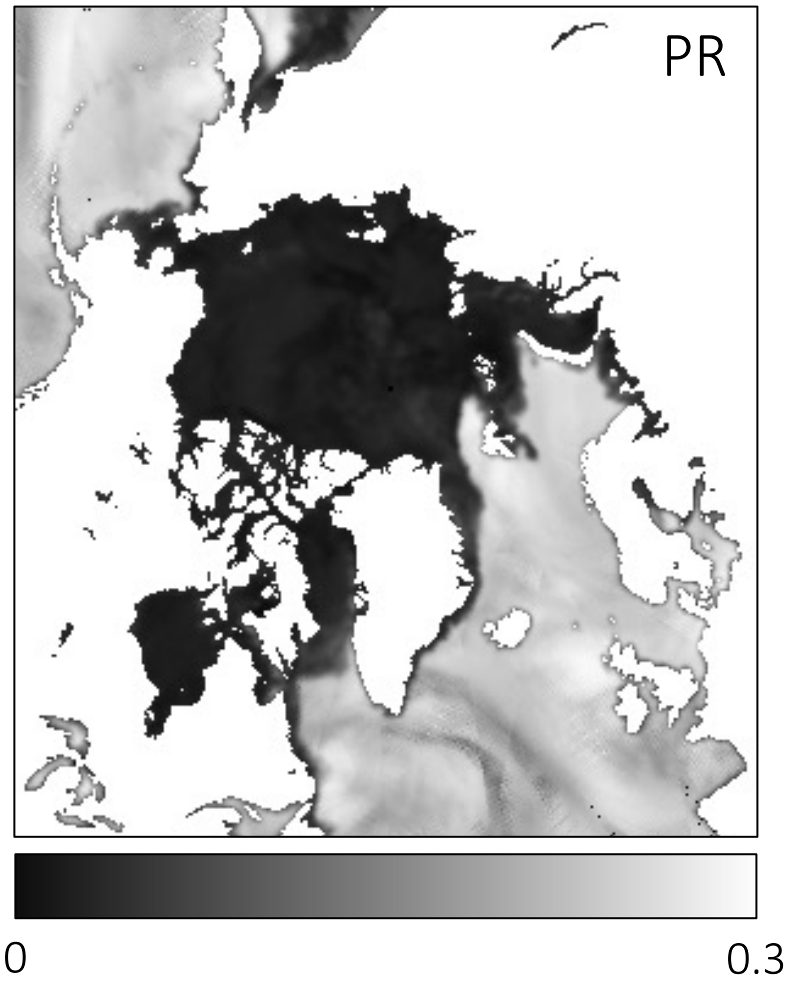
Large for water
Small for ice

Gradient Ratio:

$$GR_{[36V/18V]} = \frac{T_B[36V] - T_B[18V]}{T_B[36V] + T_B[18V]}$$

Larger for MYI
Smaller for FYI

19 March 2018



18 GHz (SMMR) ≅ 19 GHz (SSMI/SSMIS)
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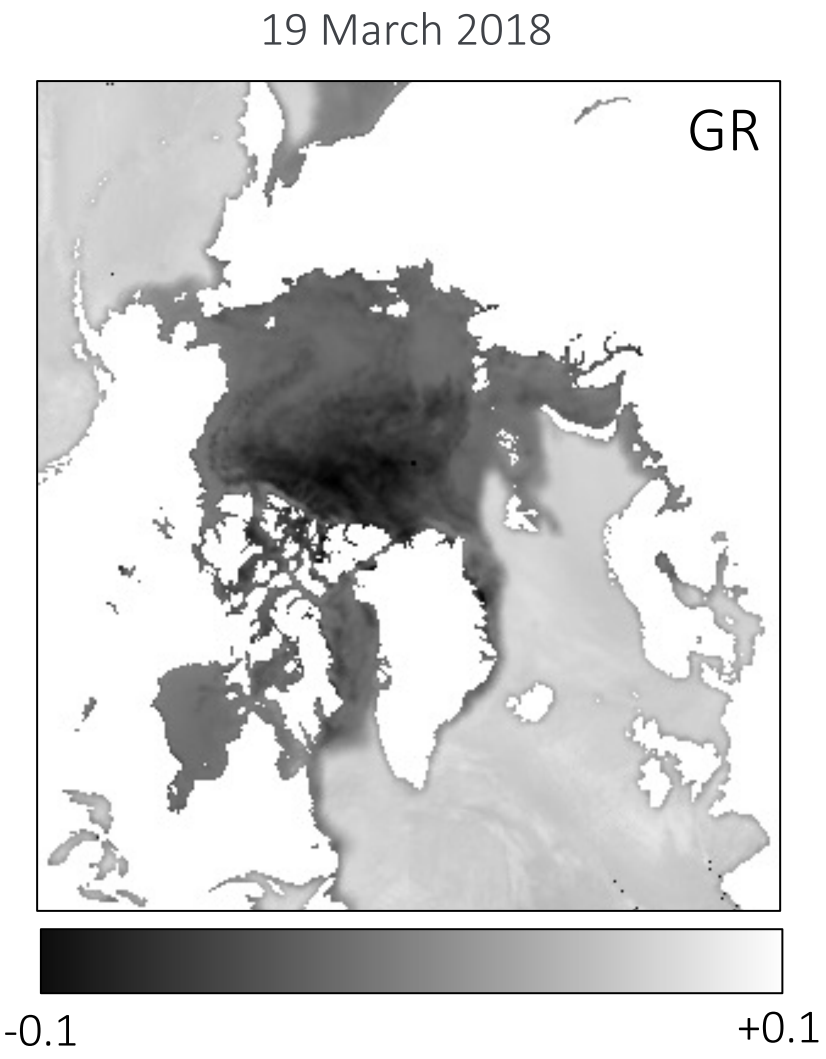

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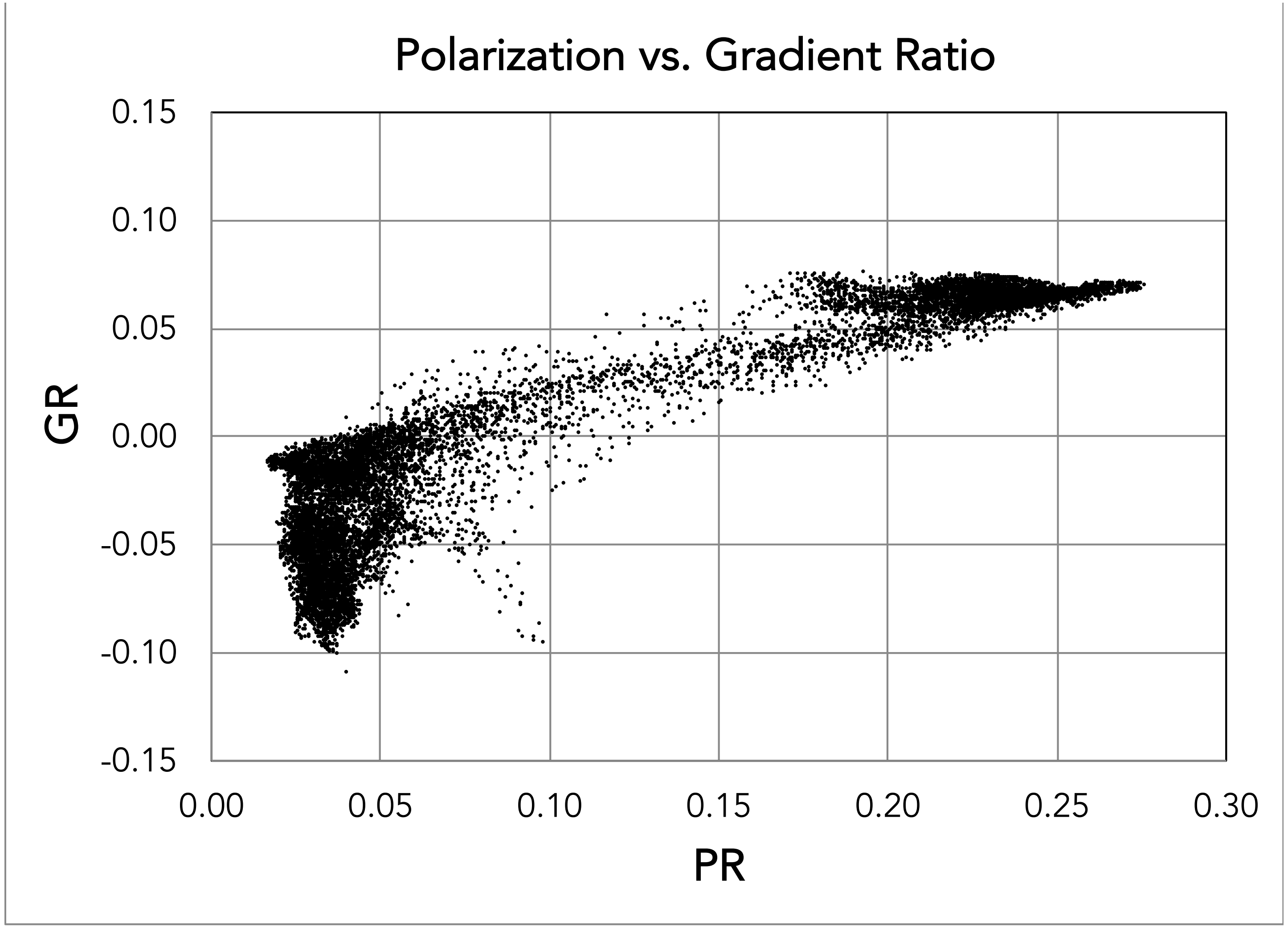
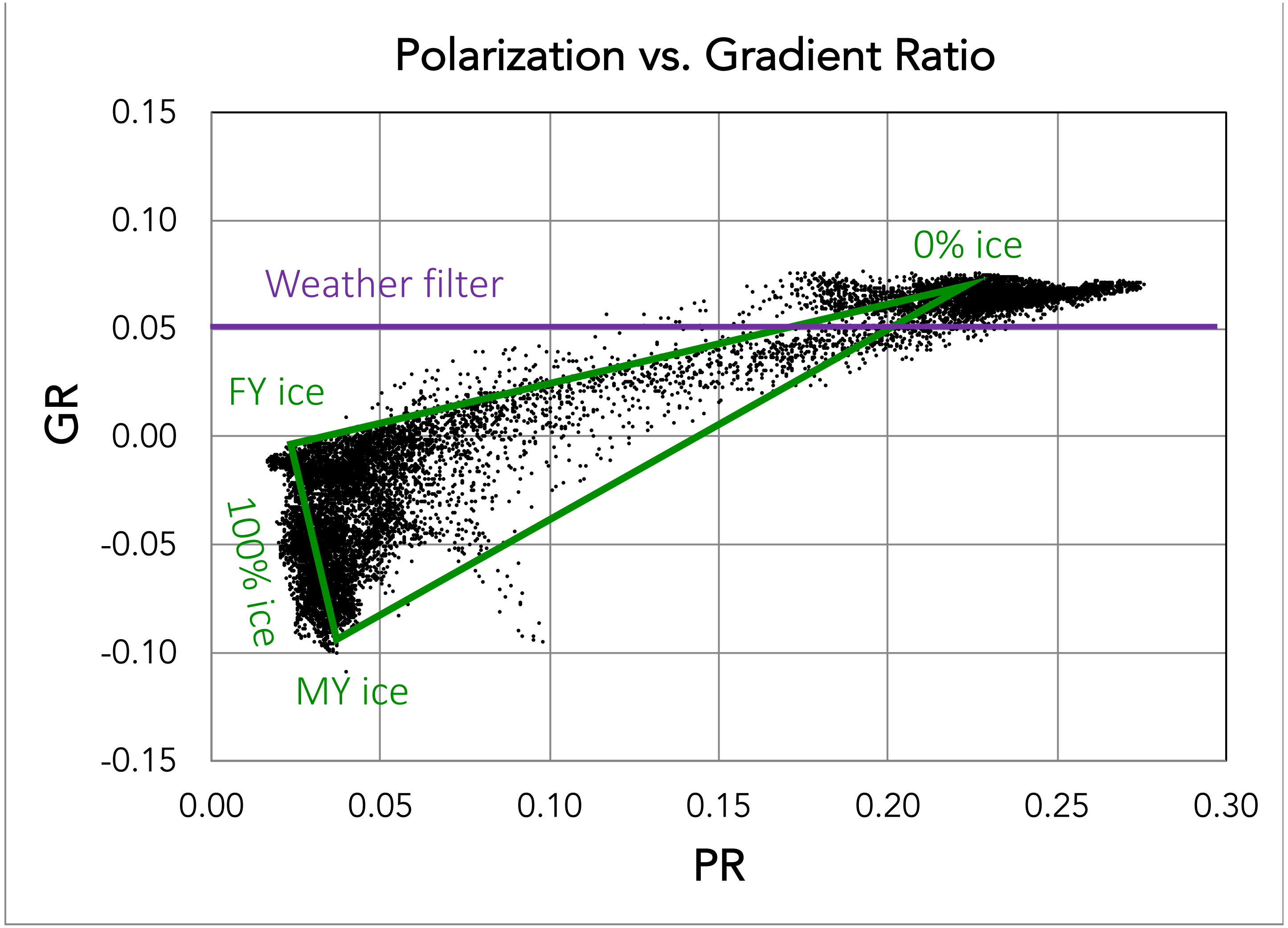
PR vs. GR → NASA Team algorithm

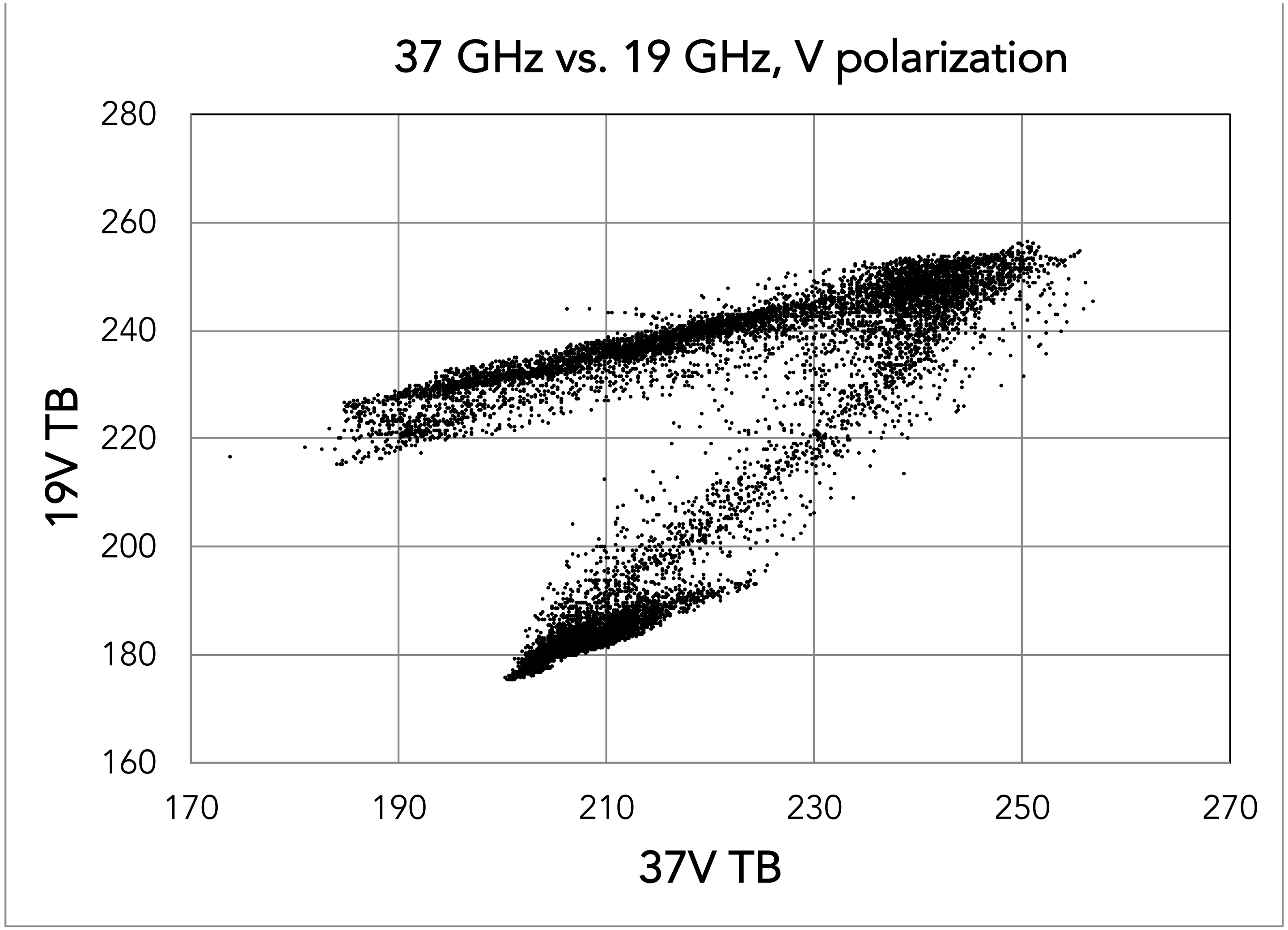


PR vs. GR → NASA Team algorithm

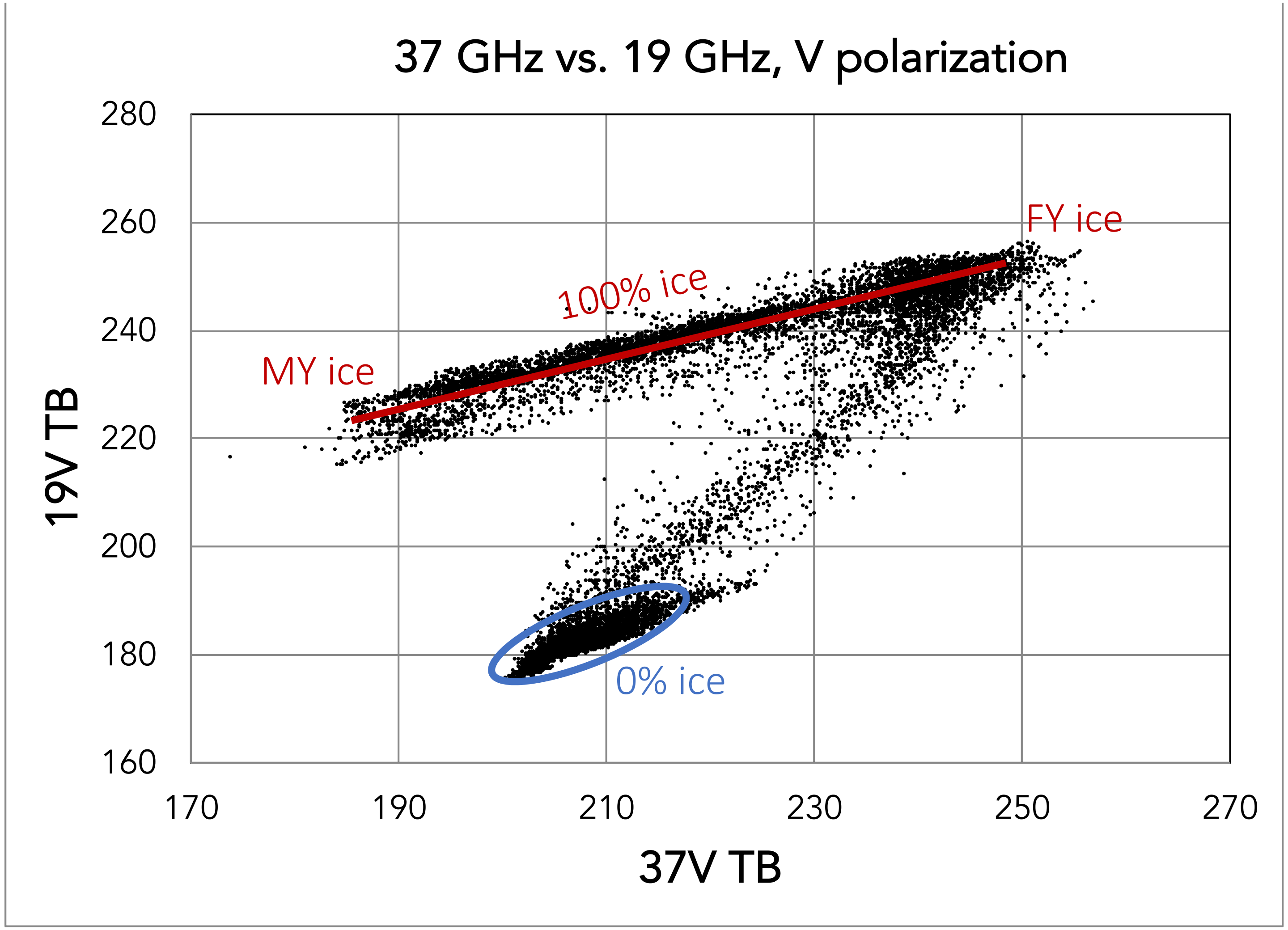


A 22V/19V GR threshold is used as an additional weather filter

Bootstrap algorithm

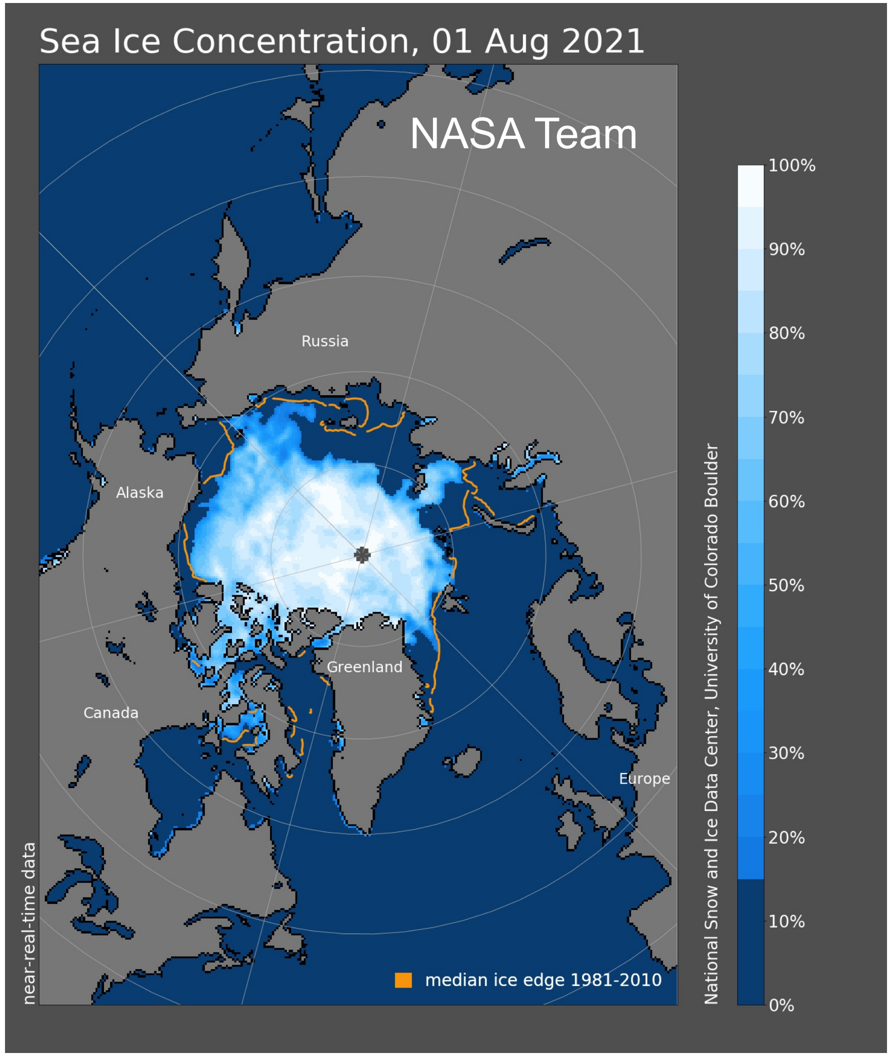


Bootstrap algorithm



NASA Goddard SIC products at NSIDC

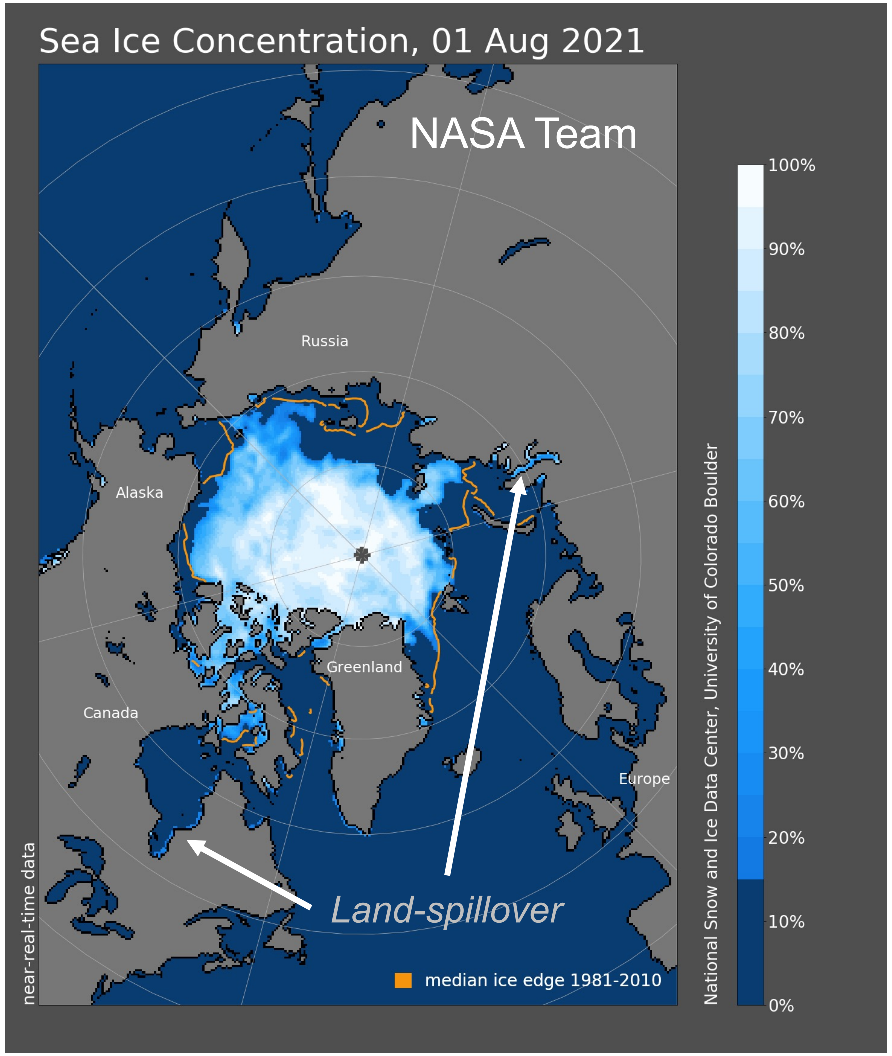
- NASA Team (NT) and Bootstrap (BT), 1978 – 2020, processed at Goddard
  - NRT NT processed at NSIDC
- Polar stereographic grid, ~25 km
- Updated 1 to 2 times per year with a 3 to 9 month lag
- Intercalibrated across sensor transitions (NT and BT independently)
  - T_B regression
  - Adjustment of algorithm coefficients
- Automated filters to remove some errors, especially weather
- Manual corrections applied to remove remaining errors



NT: Cavalieri et al., 1996, https://nsidc.org/data/nsidc-0051, doi:10.5067/8GQ8LZQVL0V
NT NRT: Maslanik and Stroeve, 1999, https://nsidc.org/data/nsidc-0081, doi:10.5067/U8C09DWVX9LM
BT: Comiso, 2017, https://nsidc.org/data/nsidc-0079, doi:10.5067/7Q8HCCWS4I0R

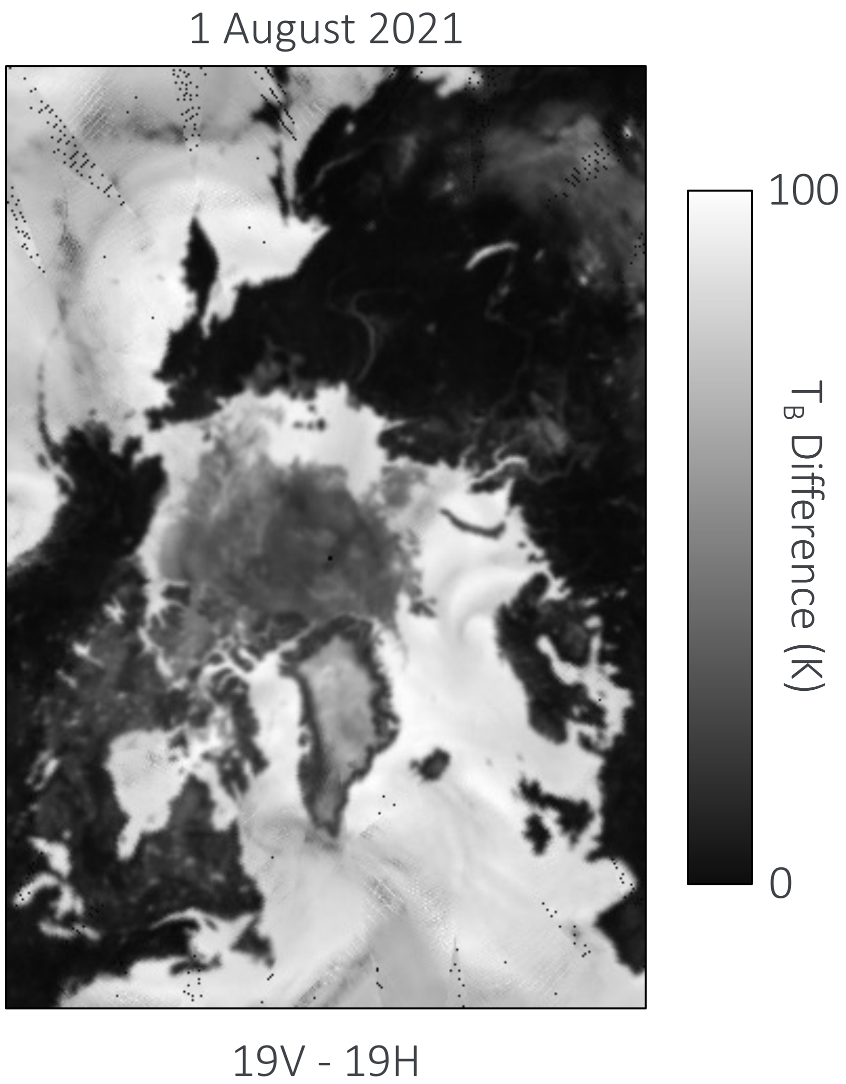
NASA Team, Bootstrap limitations

- Automated corrections not perfect
  - Land contamination remains in some areas
  - Weather filters may not remove all artifacts
- Manual corrections not tracked
- Low spatial resolution limits precision of ice edge location – overestimation and underestimation possible



NASA Team, Bootstrap limitations

- Like all PM sea ice algorithms, both tend to underestimate concentration during melt
  - Emission from surface water biases concentrations low
  - Bootstrap biases are smaller due to methodology and dynamic coefficients
- Thin ice (< ~20 cm) concentration underestimated
  - Emission from water penetrations through ice
  - Near ice edge (~50 km), ephemeral (effect over 2-3 days)
- NASA Team performance in Antarctica lower, except in cold conditions



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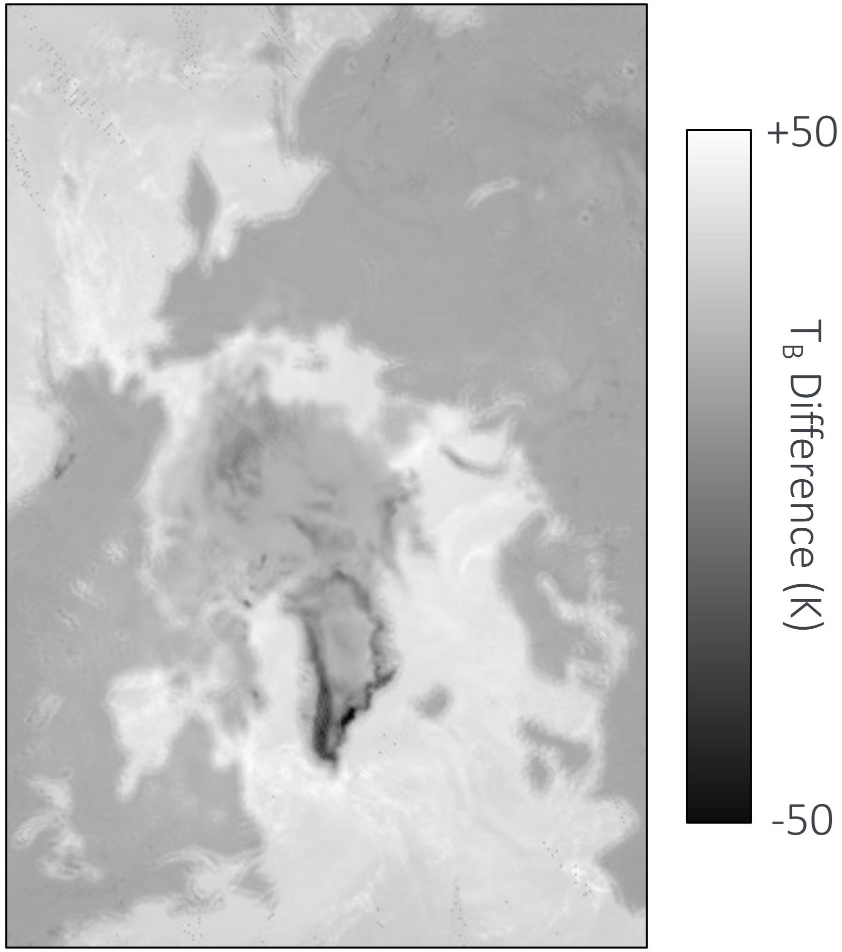
1 August 2021



37V – 19V

Snow

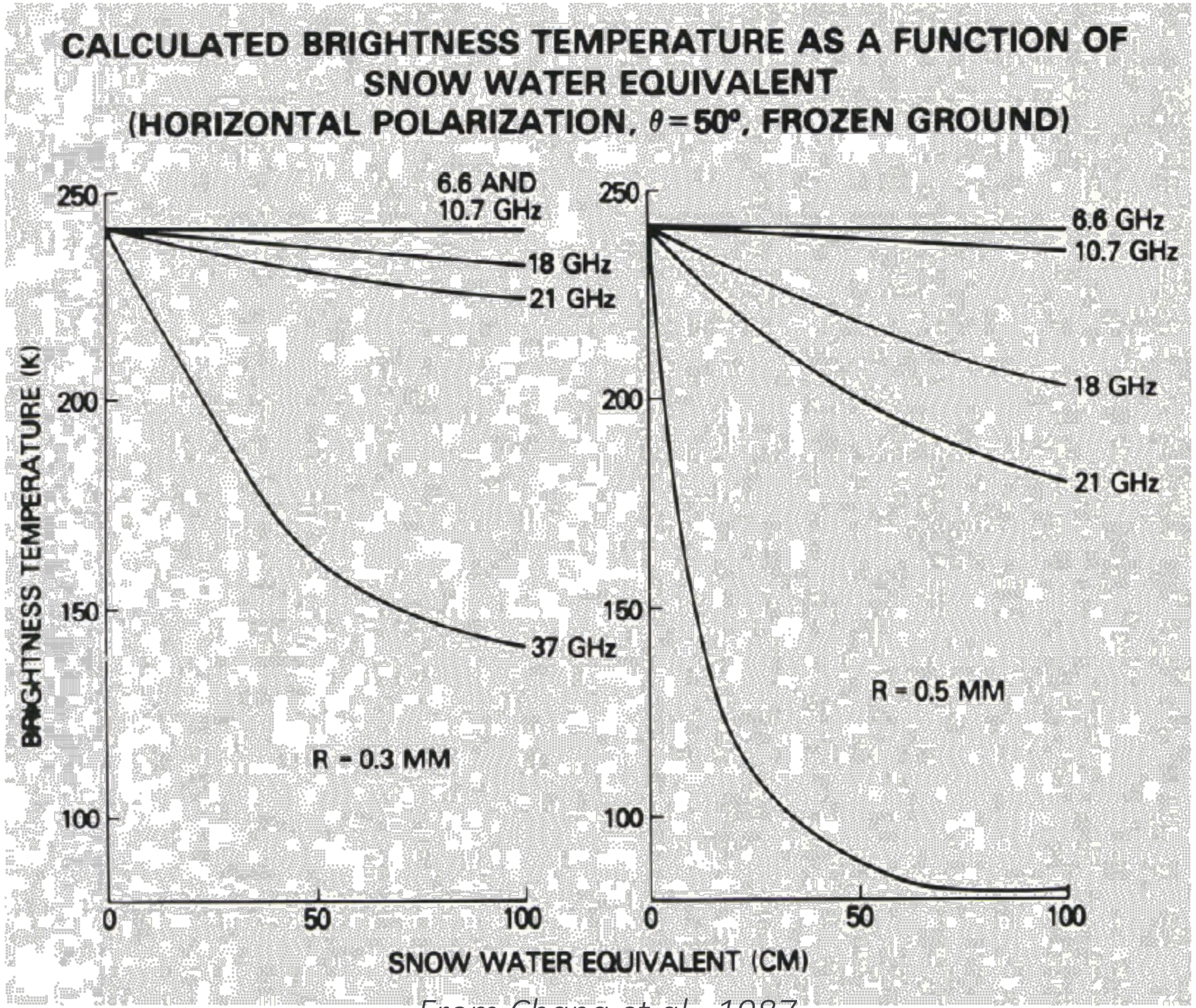
Less scattering by snow at 19 GHz than at 37 GHz

Chang algorithm
SWE equations (mm):

SMMR = $4.77*(T_B[18H] - T_B[37H])$
SSMI = $4.77*(T_B[19H] - T_B[37H]) - 23.85$

SSMIS F17 = $4.81*(T_B[19H]) - 4.79*(T_B[37H]) - 21.04$

Valid for SWE ≥ 7.5 mm

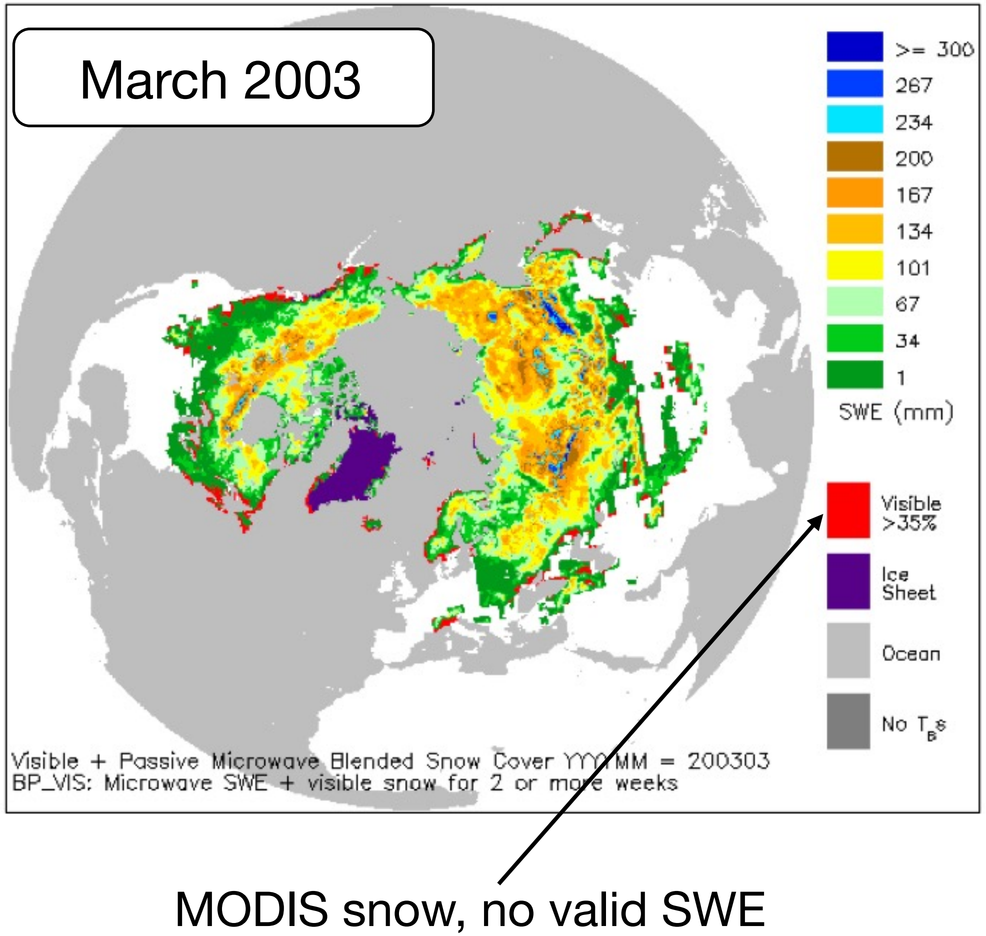


From Chang et al., 1987

Chang et al., 1987; Armstrong and Brodzik, 2001; Brodzik and Armstrong, 2013

Limitations of snow algorithm

- Very basic algorithm
- Shallow snow (< 7.5 mm) not reliably detected
- Degraded performance during melt
- No correction for forest cover and terrain



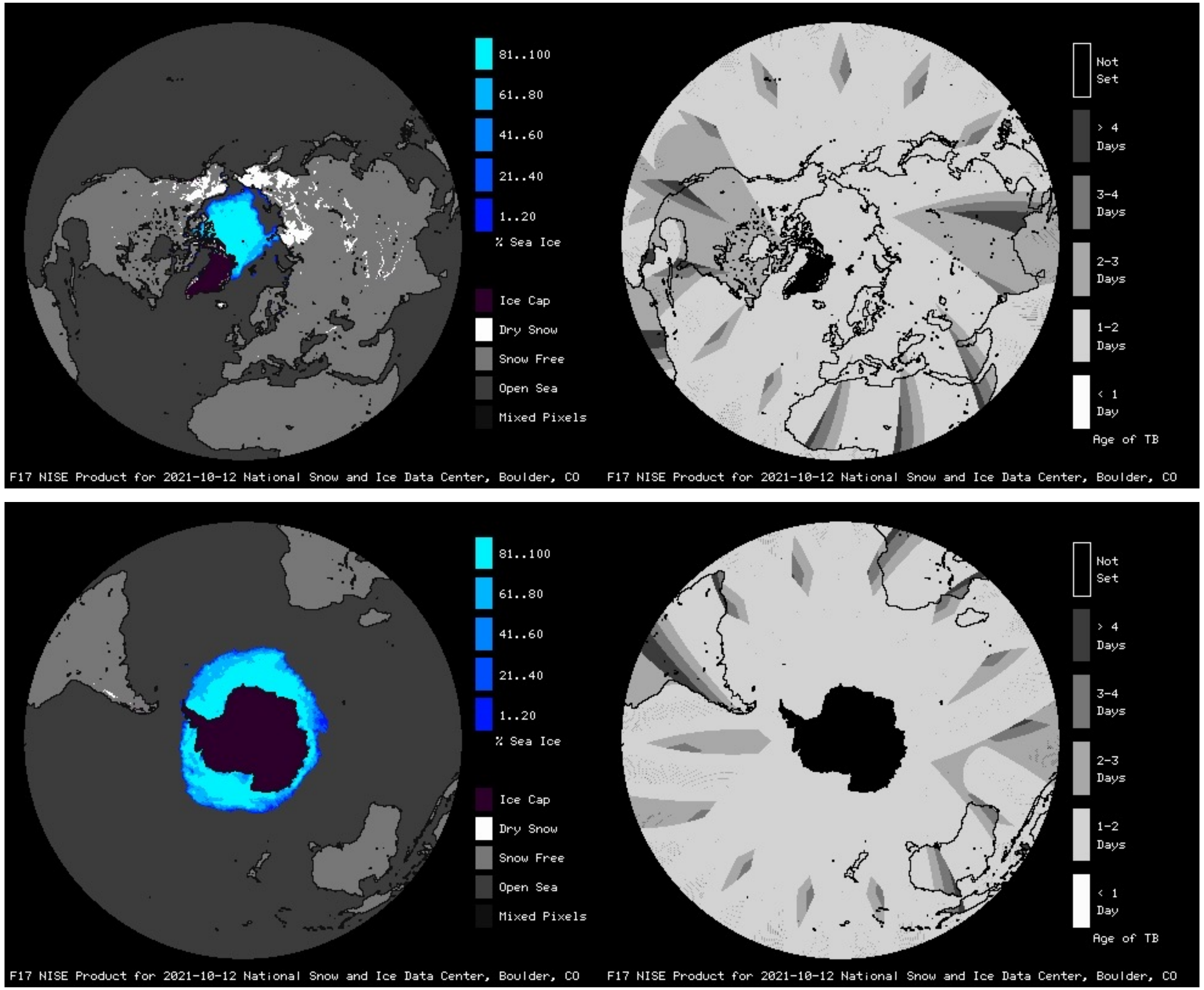
Armstrong et al., 2005, https://nsidc.org/data/nsidc-0271, doi:10.5067/KJVERY3MIBPS

Near-real-time

Ice concentration &

Snow

Extent

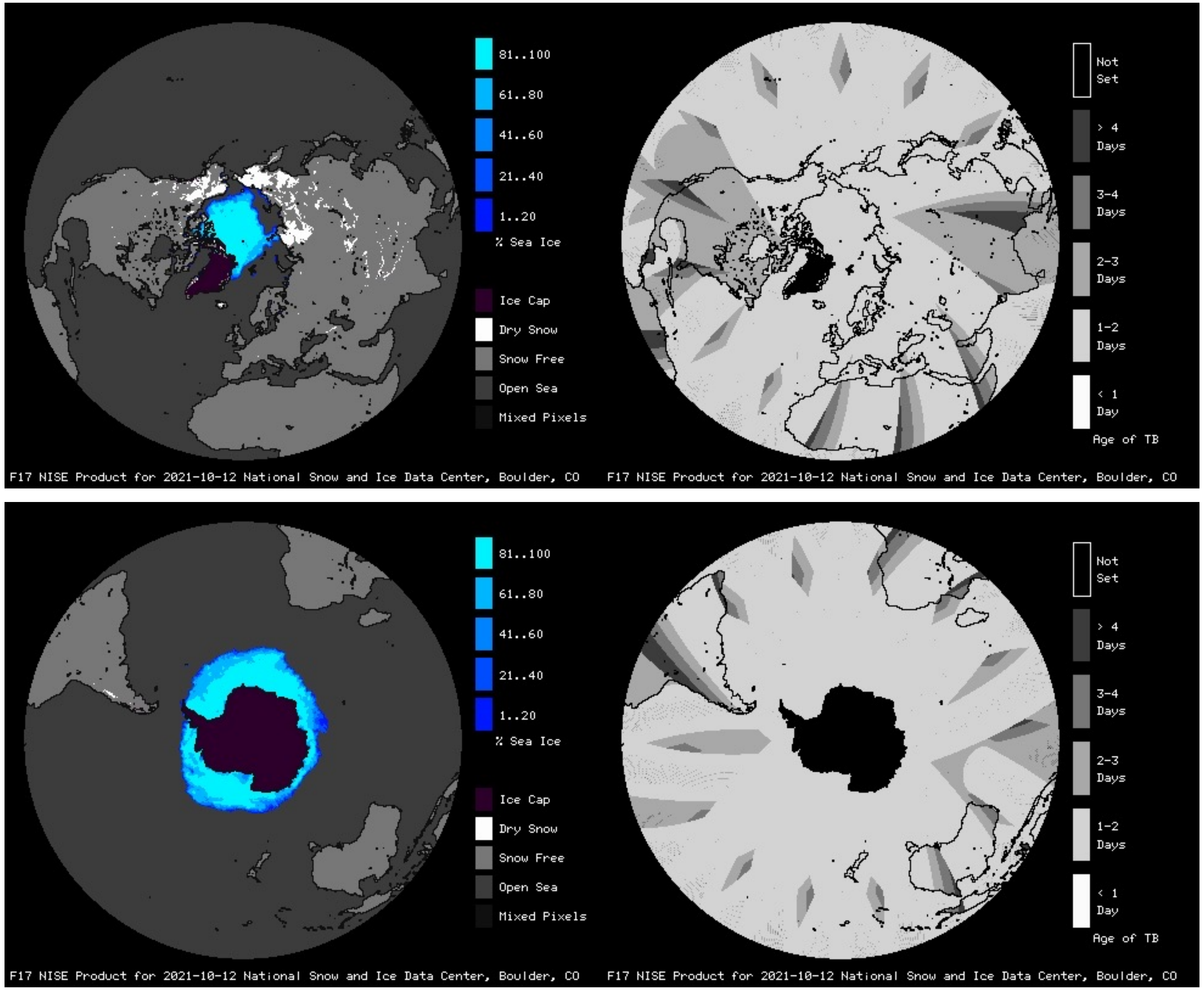


https://nsidc.org/data/nise

NISE background and history

- Started in 1997 – support for EOS missions
- Provide NRT combined snow and sea ice field
- Complete fields needed → up to 5-day compositing
- At the time, it was the only quasi-NRT product at NSIDC

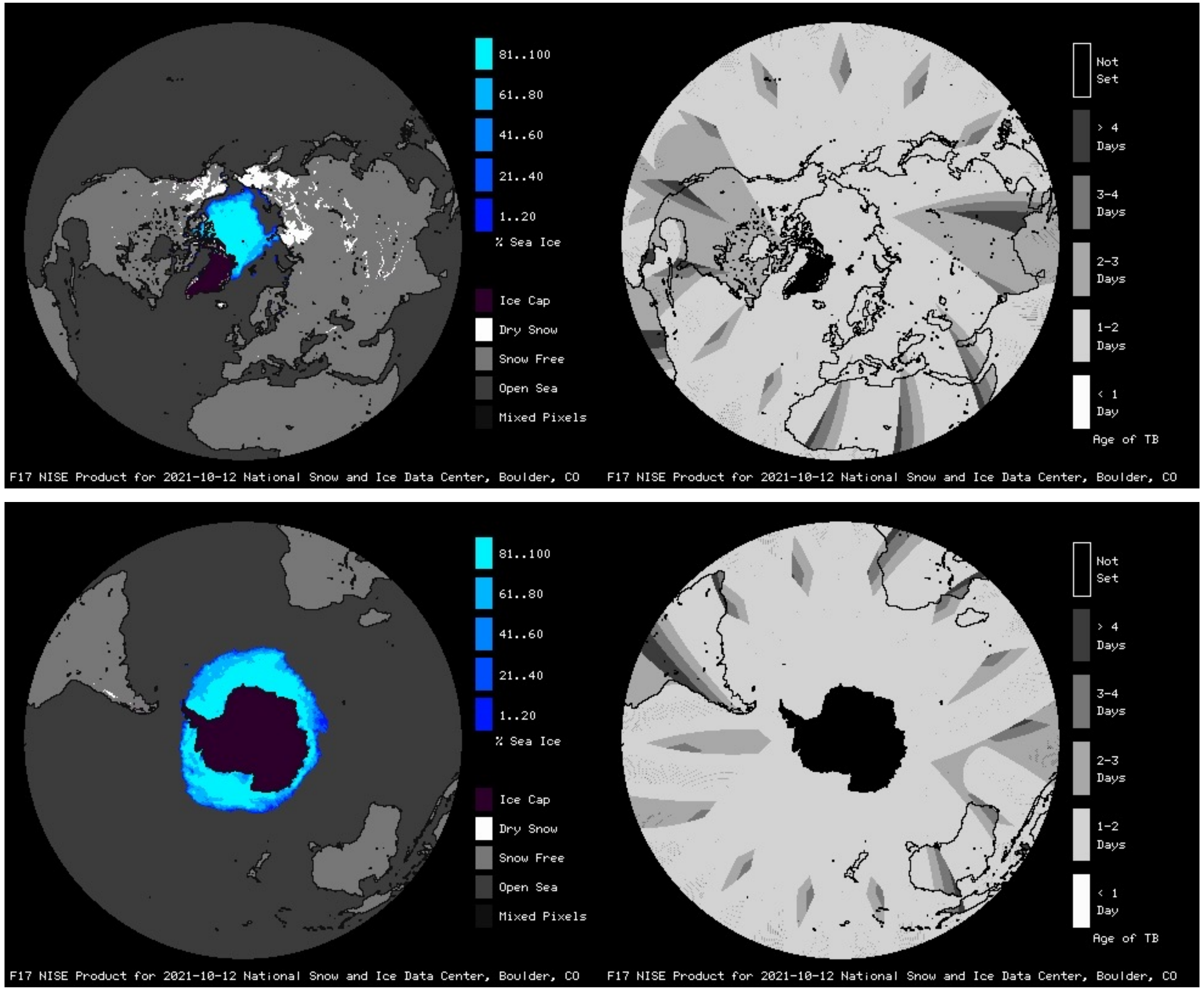
- NH and SH EASE Grid
- NASA Team sea ice concentration algorithm
- Adapted Chang snow algorithm (SWE ≥ 7.5 mm → snow)



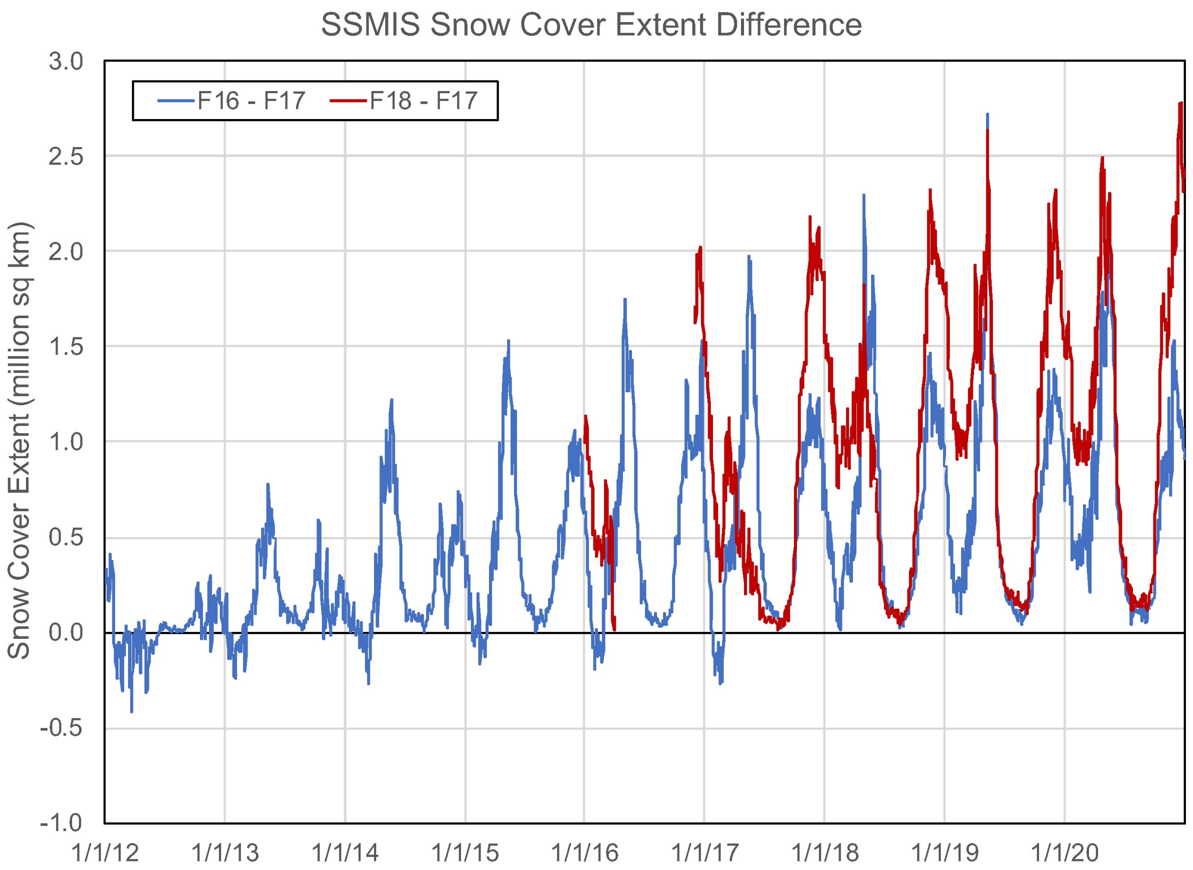
NISE background and history

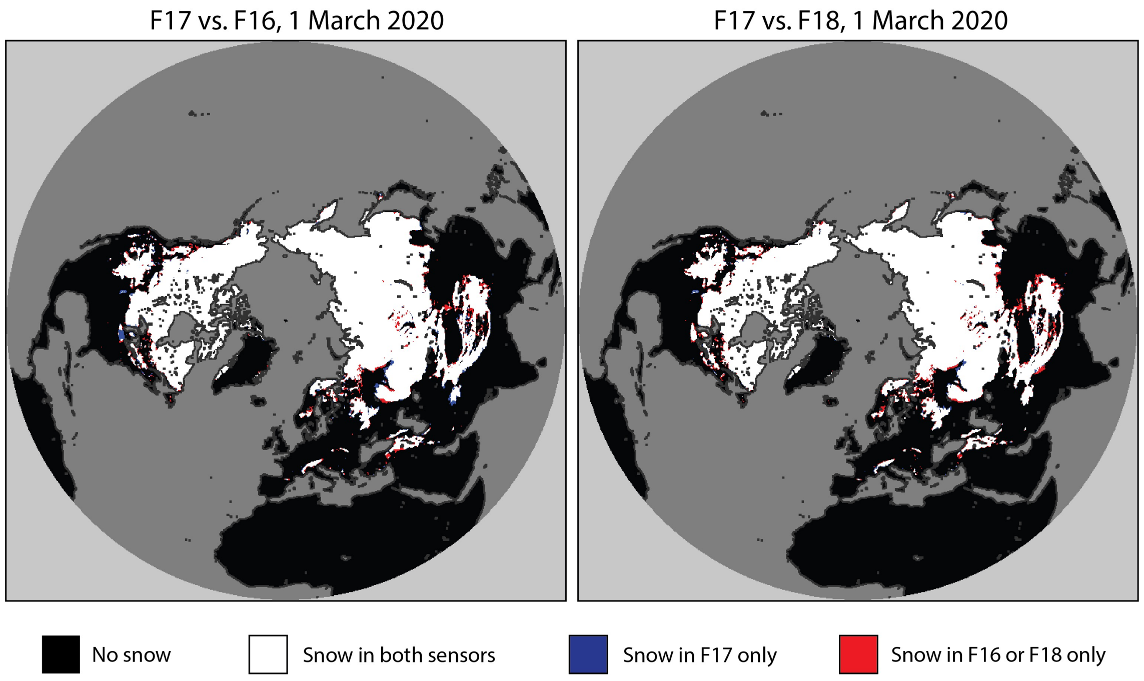
- V1 (1997): initial operational release with F13 SSMI
- V2 (2005): full F13 mission provided (starting May 1995)
- V4 (2009): transition to F17 SSMIS, adjusted coefficients
- V5 (2021): F18 SSMIS added as a back-up
- V3 (2021): F16 SSMIS added as an alternative

Fields from all three sensors (F16, F17, F18 SSMIS) now available

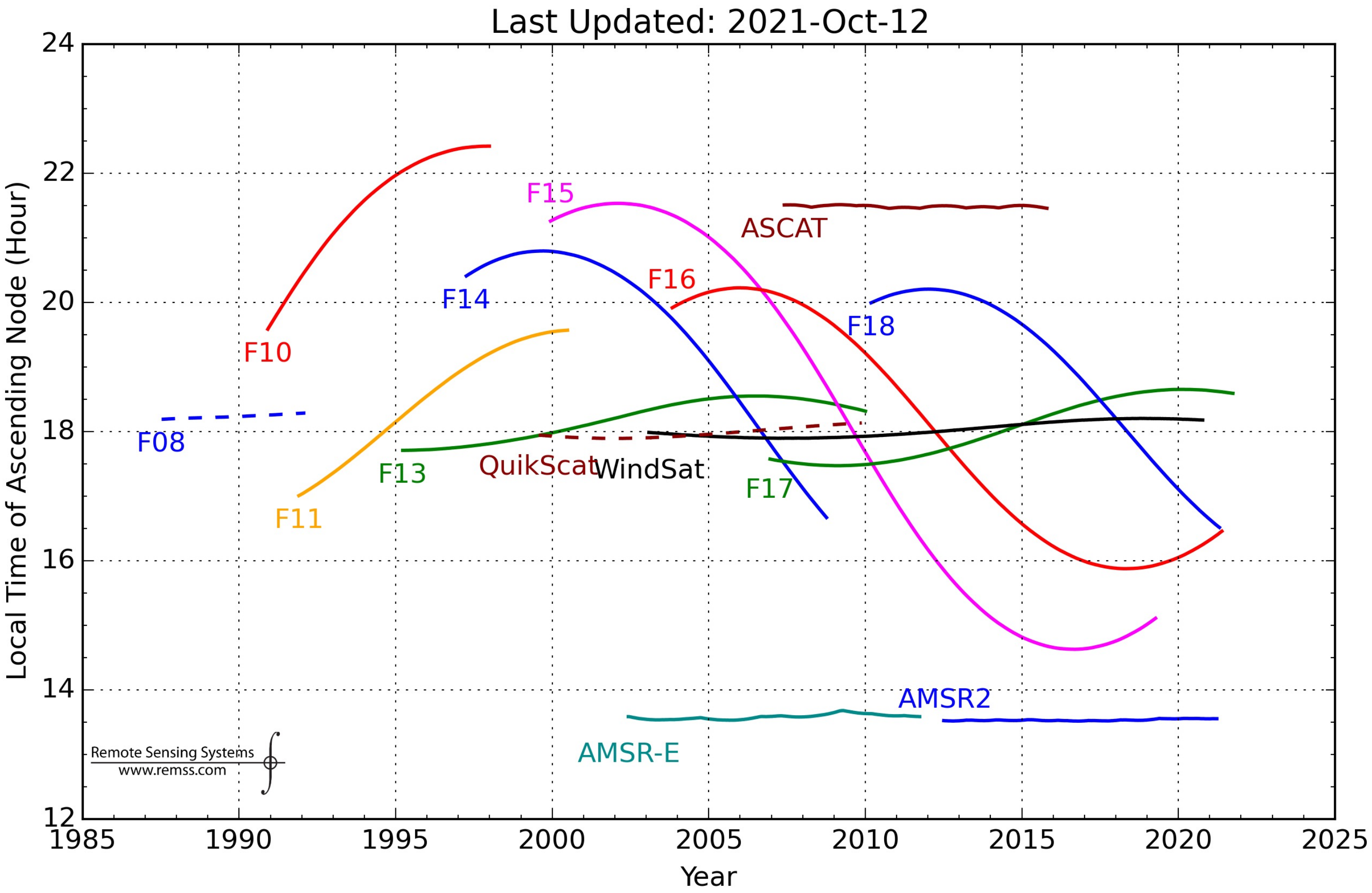


NISE F16, F17, F18 and recent adjustments





DMSP crossing times



https://www.remss.com/support/crossing-times/

NISE adjustments for SCE

- Original F16, F18 SSMIS intercalibration done in 2016
- Redone in 2021 based on 2019 and 2020 data
- Coefficients adjusted to create best overall match with F17 SSMIS

SWE algorithm:

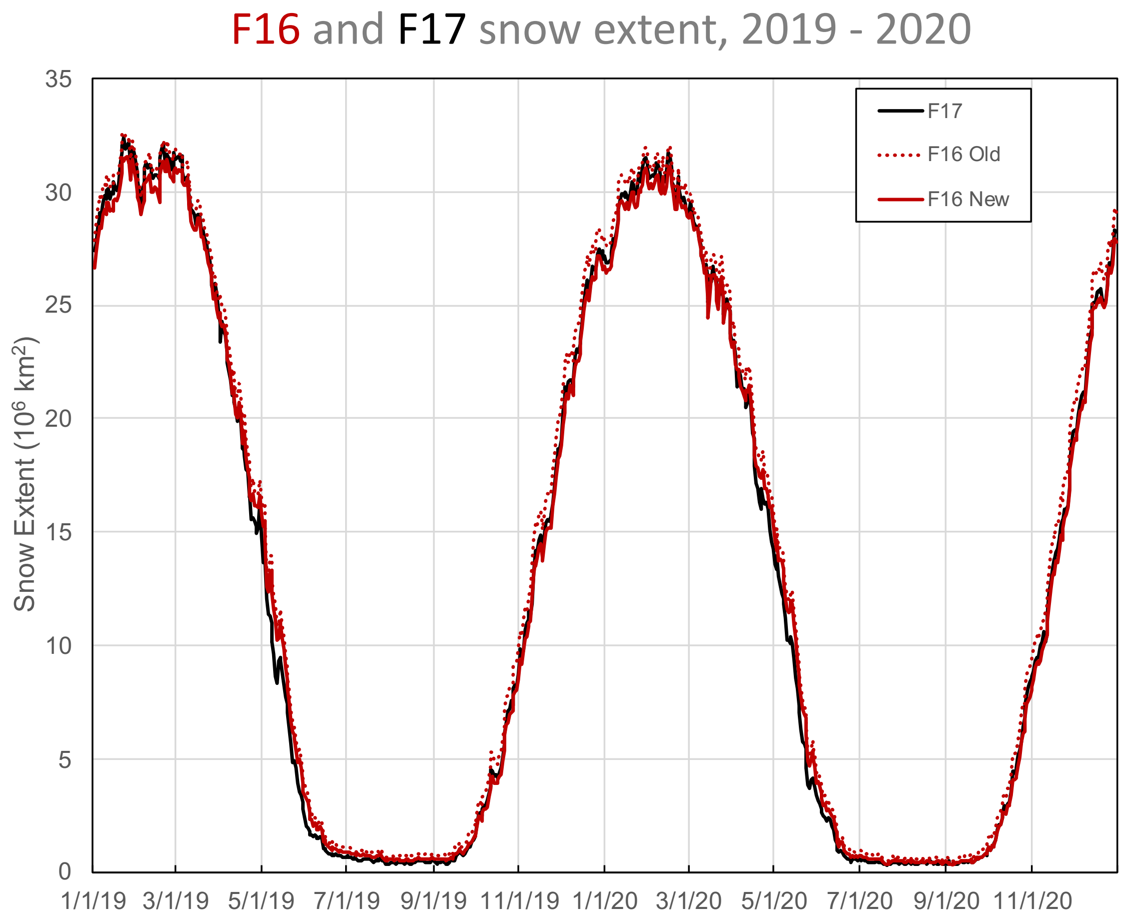
$F17 = 4.81*(T_B[19H]) – 4.79*(T_B[37H]) – 21.04$

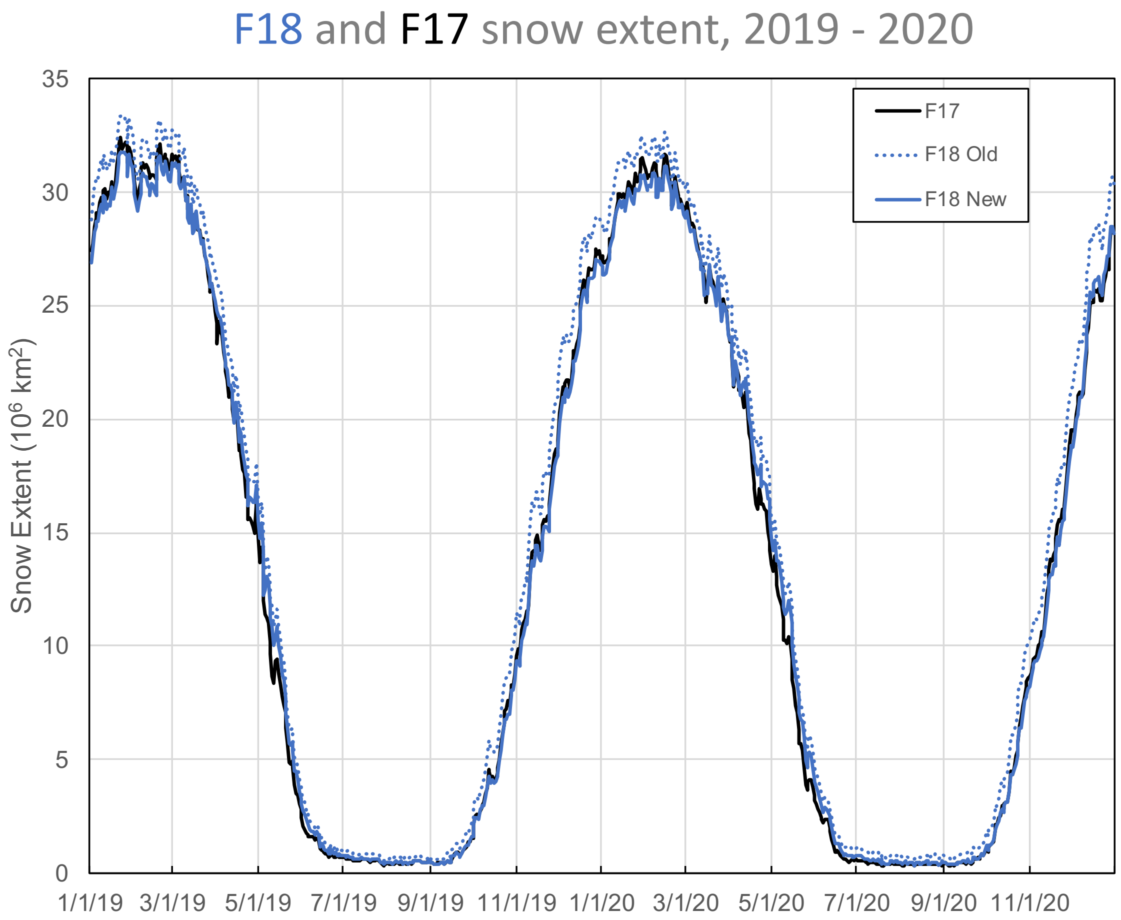
$F16 = 4.81*(T_B[19H]) – 4.81*(T_B[37H]) – 21.11$

$F18 = 4.87*(T_B[19H]) – 4.83*(T_B[37H]) – 33.54$

Valid for SWE ≥ 7.5 mm

NISE F16, F17, F18 and adjustments



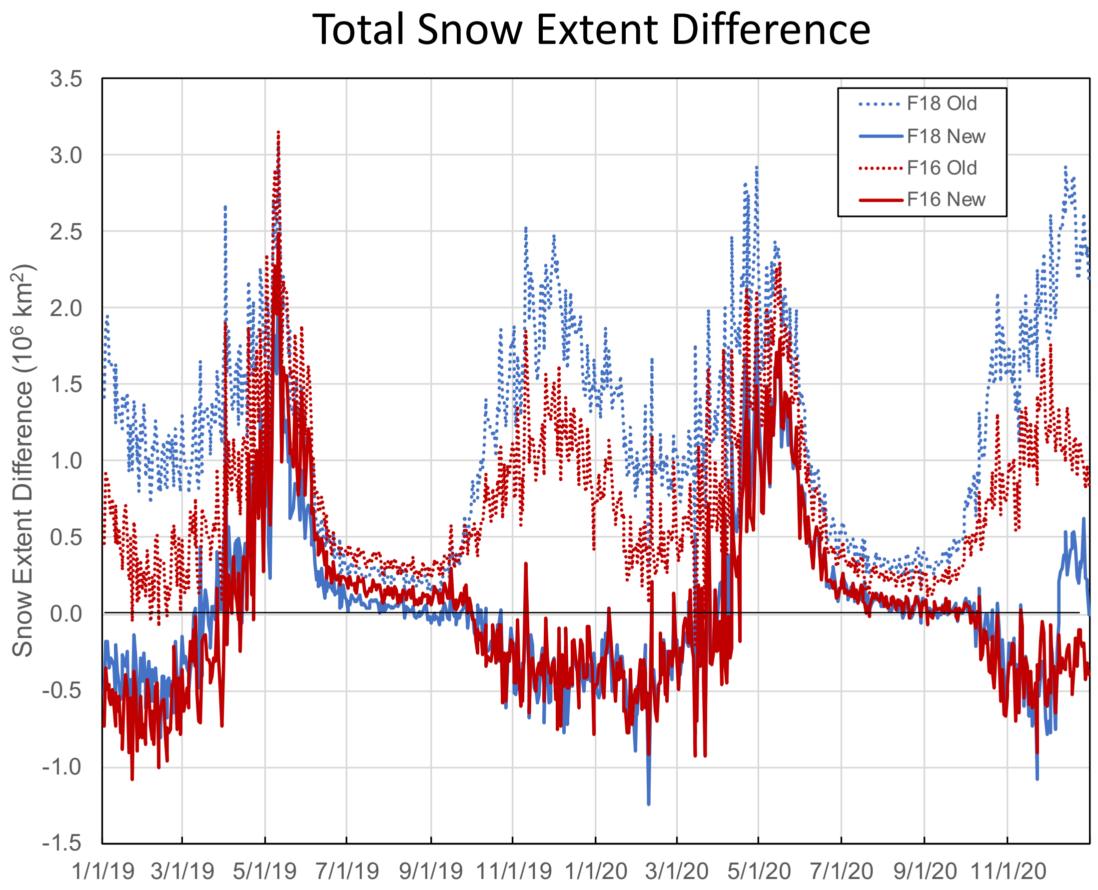


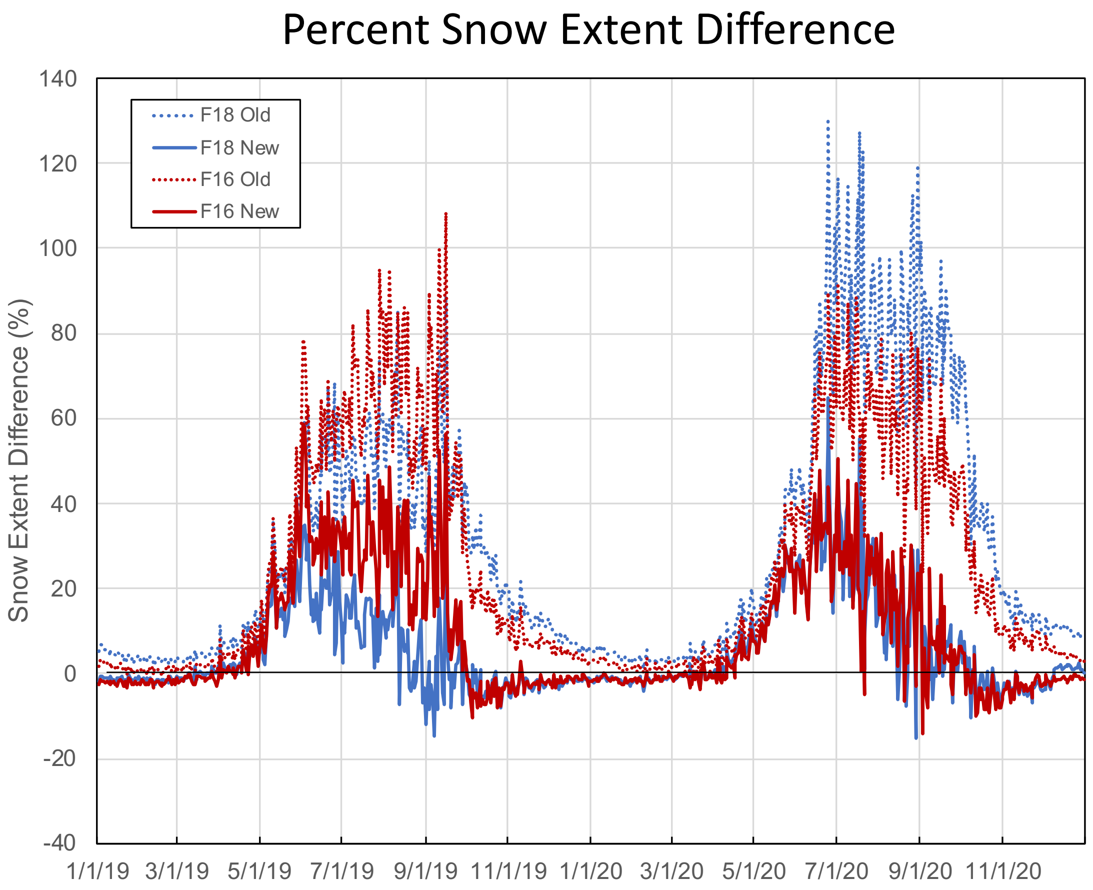
NSIDC

NSIDC DAAC

CIRES

NISE F16, F17, F18 and adjustments





NISE future enhancements

- Continue monitoring extents and algorithm coefficients
- Output format from HDF-EOS to NetCDF
- Grid from EASE to EASE2
- Rewrite code into Python 3.X
- Other possibilities:
  - Replace NASA Team with Bootstrap or CDR algorithm?
  - Extrapolate snow to coast?
  - Provide an estimate of ice in lakes?

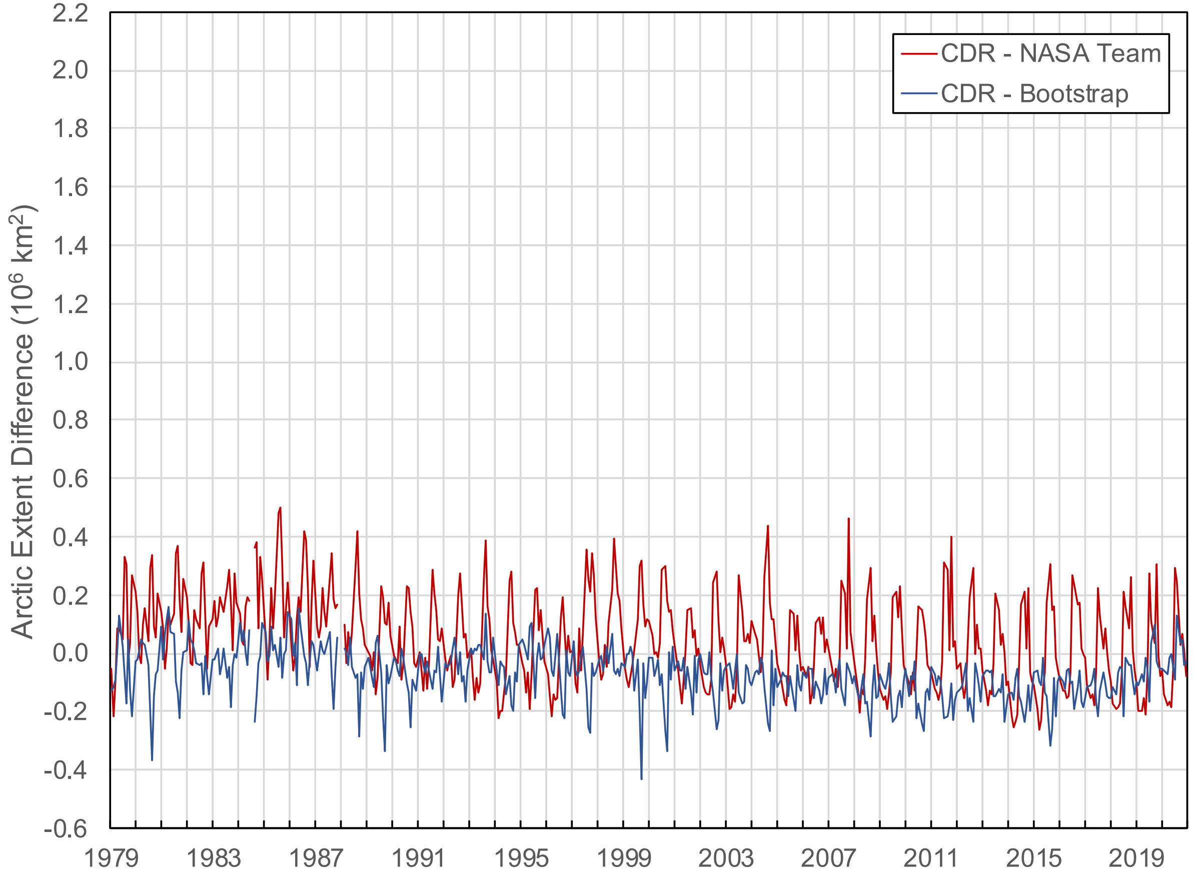
NOAA/NSIDC SIC Climate Data Record

- Based on NASA Team and Bootstrap algorithms from Goddard
- Focus on consistency, provenance to meet CDR requirements
- No manual corrections – fully reproducible
- Original version released in 2011
- Version 4 released in June 2021; updates include:
  - Added SMMR period (1978 – 1987)
  - New version (V3.1) of Bootstrap algorithm
  - Spatial and temporal interpolation to fill missing data
- NRT version (ICDR) released in 2017
  - Same algorithms as CDR, but NRT input TB fields for an interim product
  - Updated in June 2021 to be consistent with CDF

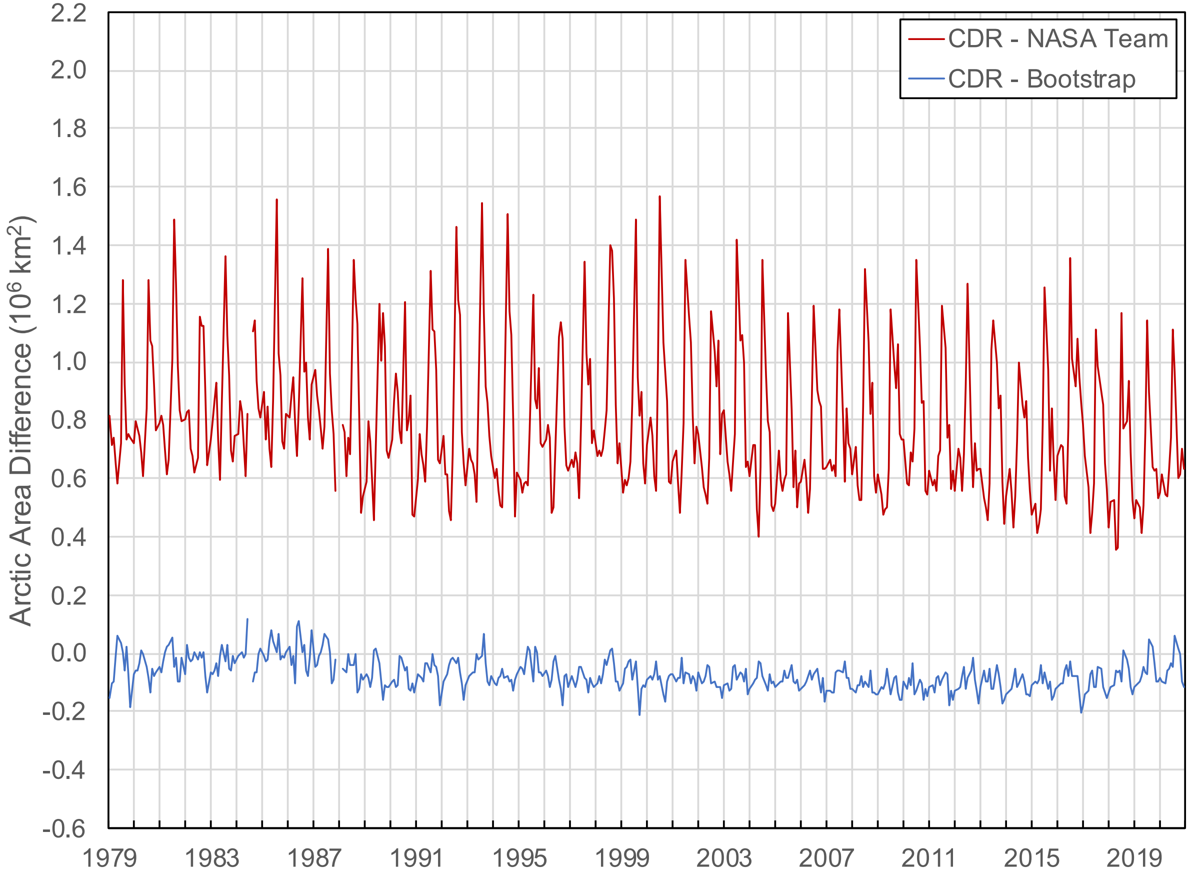
CDR: Meier et al., 2021, https://nsidc.org/data/g02202, doi:10.7265/efmz-2t65
ICDR: Meier et al., 2021, https://nsidc.org/data/g10016, doi:10.7265/tgam-yv28

CDR vs. NT and BT

Northern Hemisphere Extent

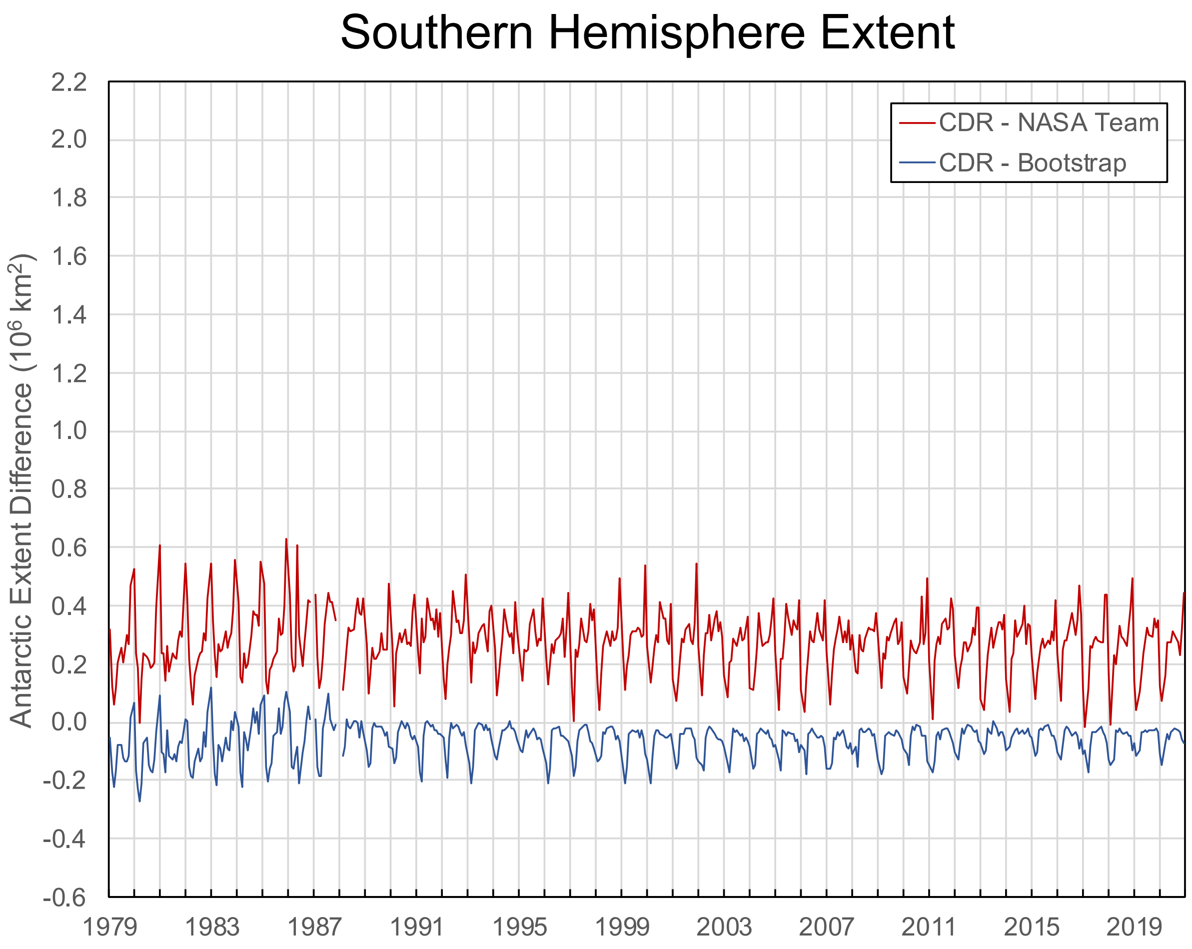


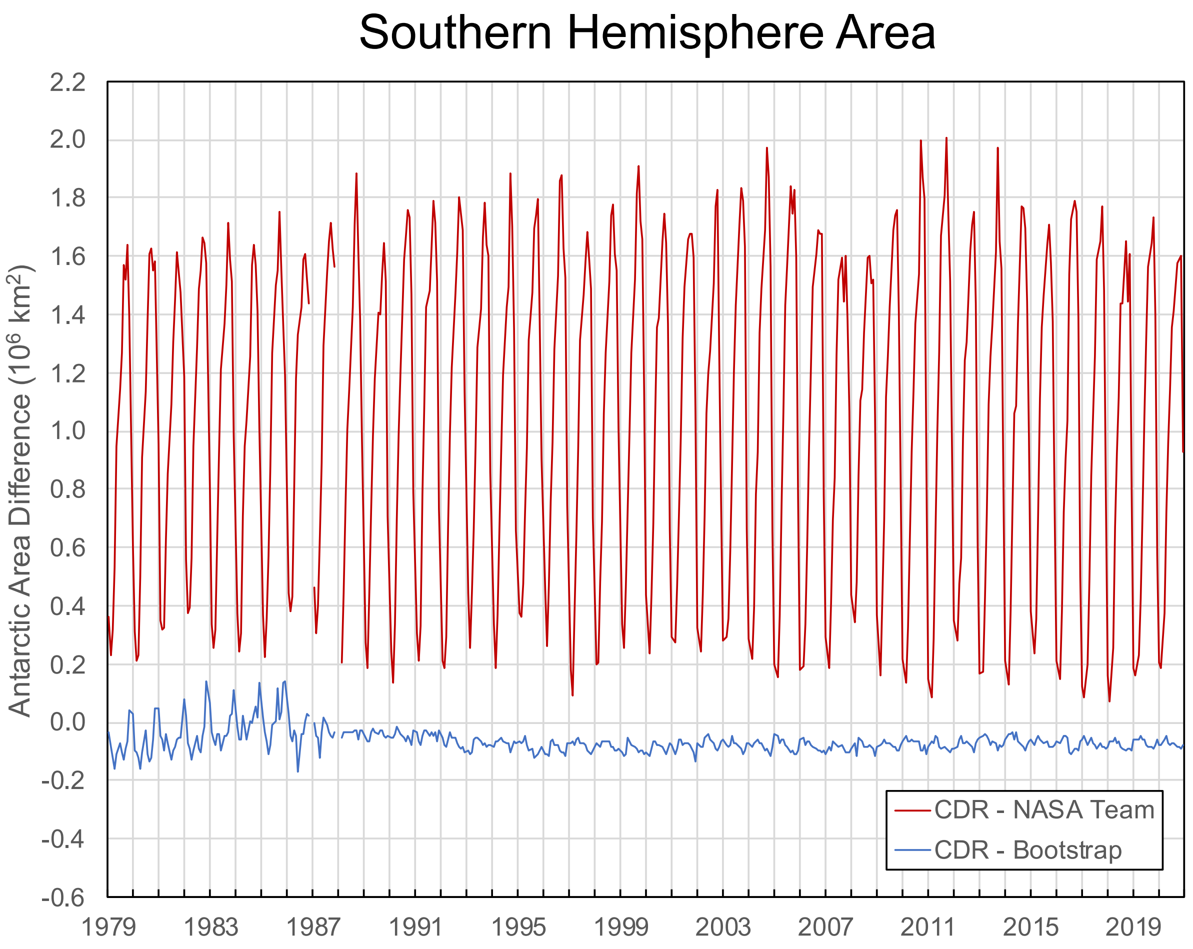
Northern Hemisphere Area



Sea ice extent = sum of total grid cell area where concentration > 15%
Sea ice area = sum of total ice-covered area > 15% (area weighted by concentration)

CDR vs. NT and BT





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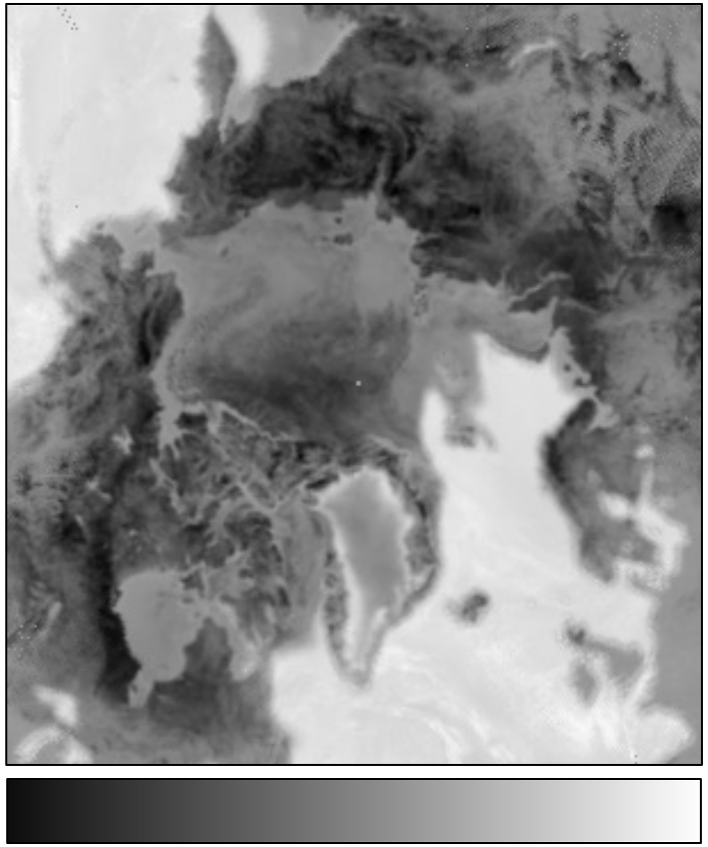
Sea ice age

- Passive microwave emission sensitive to salinity in the ice
- Multiyear ice (MYI) flushed by summer melt → lower salinity than first-year ice (FYI)

37V – 19V, 19 March 2018



-50 +50

Brightness Temperature Difference (K)

Multiyear ice "colder" at 37 GHz than at 19 GHz

- 37V < 19V for multiyear ice
- 37V ≈ 19V for first-year ice

F18 SSMIS gridded brightness temperatures

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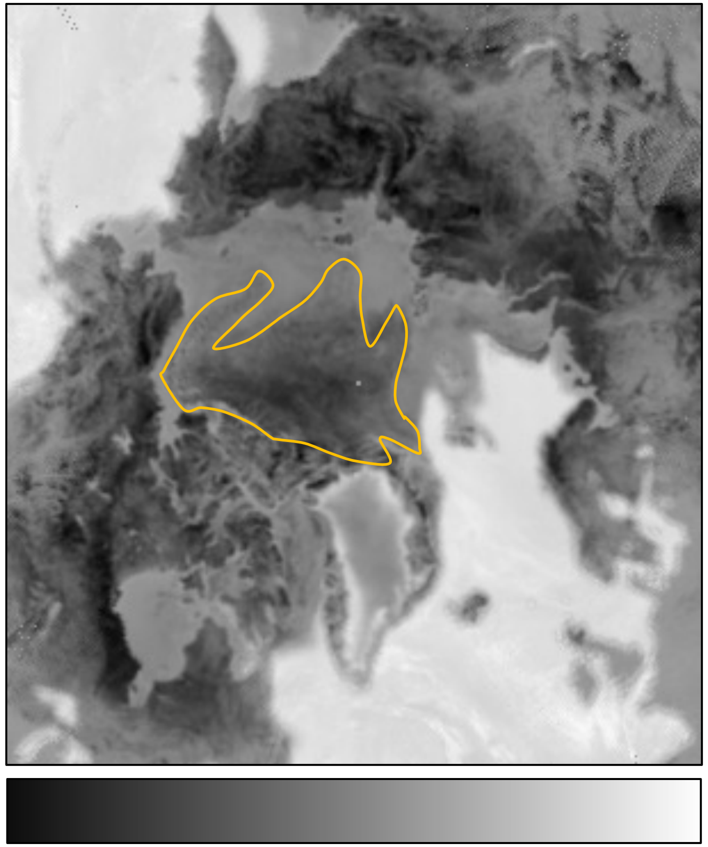

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F18 SSMIS gridded brightness temperatures

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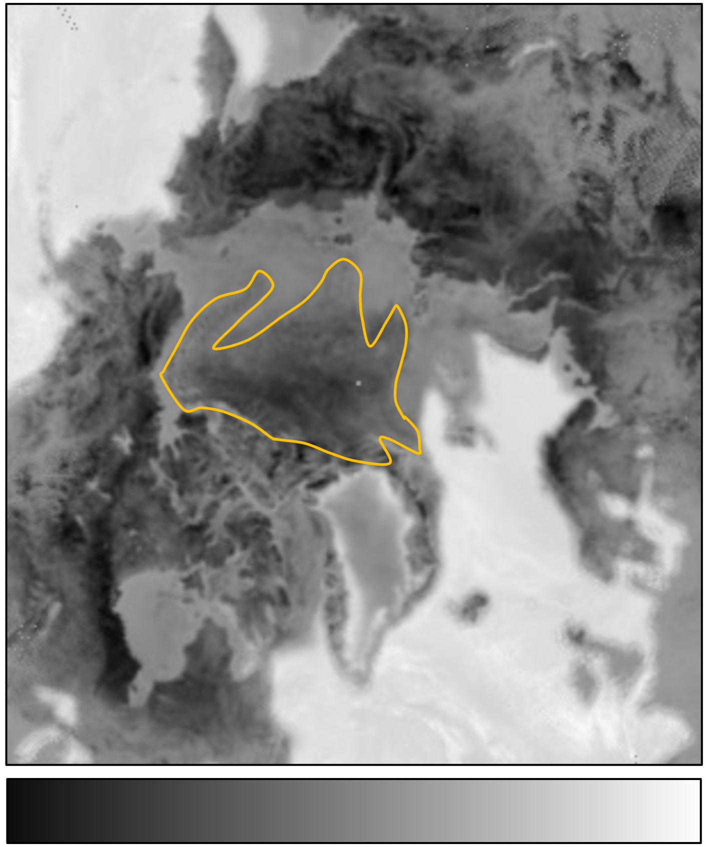
- Identifying dominant ice-type works reasonably well in winter, but concentration estimates unreliable
- Thick snow on FYI has similar signature to MYI
- Identification not reliable during melt conditions

37V – 19V, 19 March 2018



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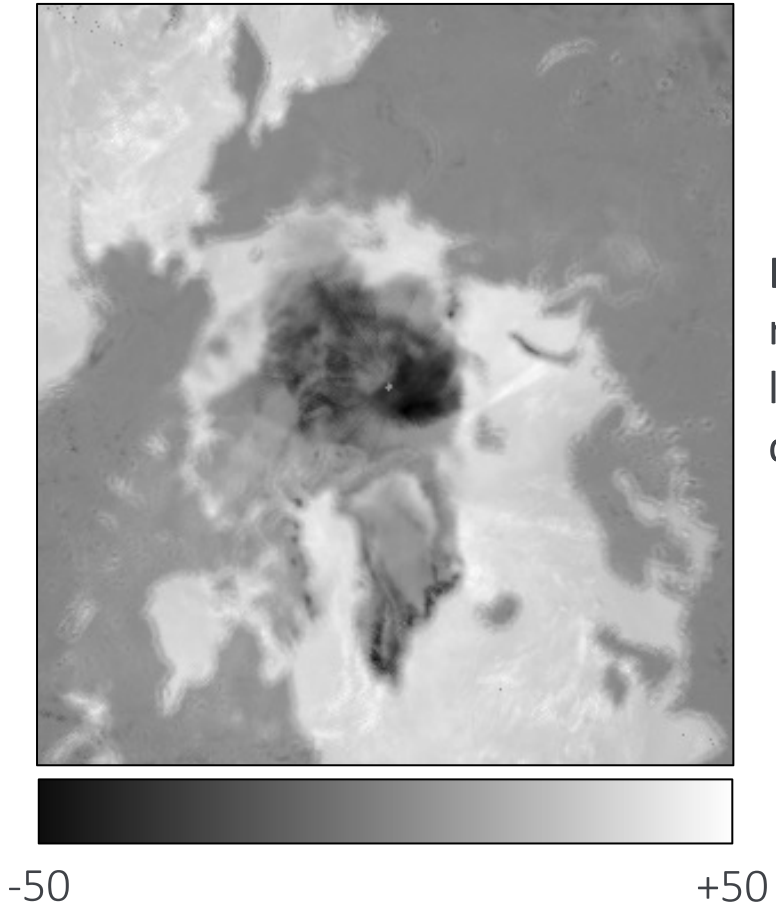


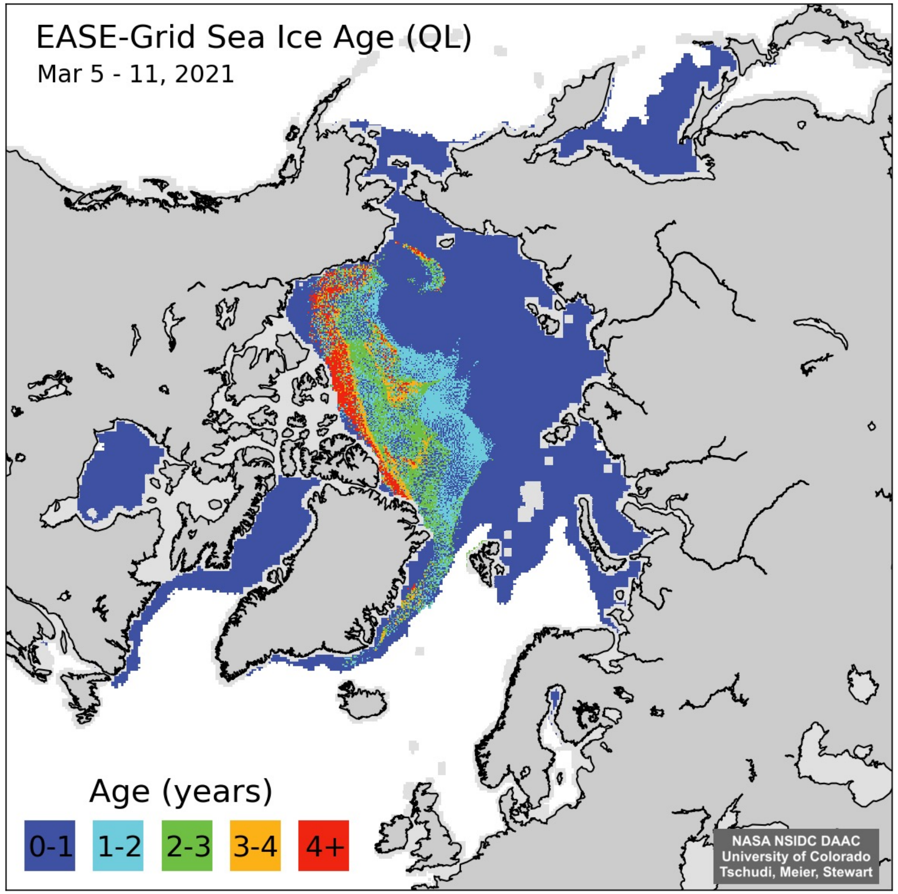
Brightness Temperature Difference (K)

During melt, 37V vs. 19V relationship is inconsistent; liquid water on surface is dominating emission

F18 SSMIS gridded brightness temperatures

Another approach to sea ice age

- Lagrangian tracking of ice parcel
- Motion estimated from cross-correlation feature tracking
- Daily motions very “noisy” as passive microwave spatial scales
- Weekly average motions smooth out noise
- Tracking has only one ice age class, corresponding to oldest ice in the parcel → no concentration/distribution statistics
- NSIDC DAAC ”quicklook” weekly age product updated once per month



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Summary

- NSIDC DAAC PM products provide consistent long-term record, and near-real-time concentrations
  - Lower spatial resolution
  - Limitations during melt
- NISE has a long heritage;
  - Adjustments for sensor transitions, but few other changes
  - Plan to make improvements in coming year
- CDR algorithm combination improves performance
- Feedback from the CERES community is welcome